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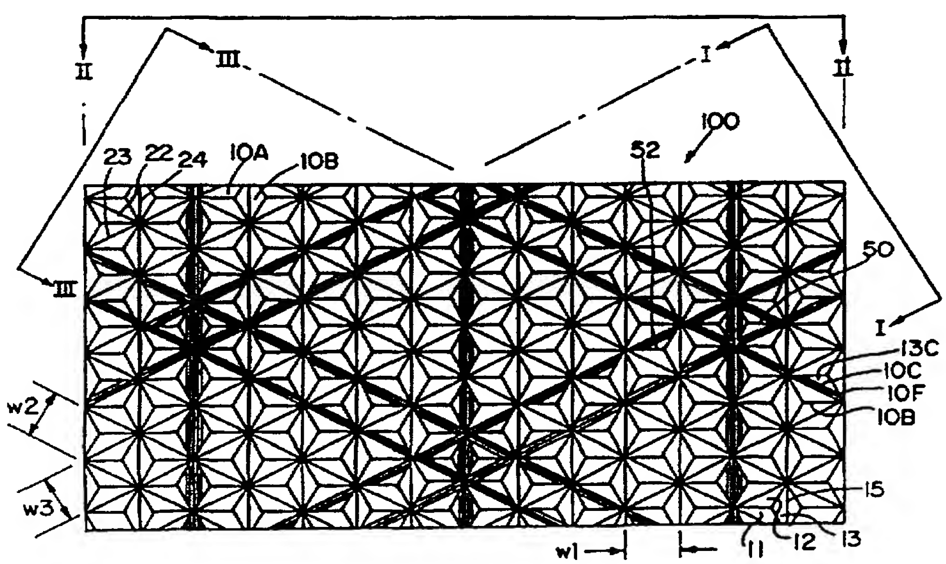

(57) Abstract

Cube-corner retroreflective articles having wide observation angle performance, uniform orientation angle performance and wide angularity in multiple viewing planes are provided by very small (0.0005 inch to less than 0.0006 inch) size prism elements (10) in which pairs (10A, 10B) of such elements are tilted; preferably in a negative direction. In an alternate embodiment, retroreflective prisms are formed with windows (10F) thereon by removing a portion of the prism mold on one prism pair (10B, 10C) leaving the apex of the prism intact. In this manner smaller prisms are formed adjacent larger prisms.

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RETROREFLECTIVE TILTED PRISM STRUCTURE

Background of the Invention

Retroreflective structures of the type utilized herein are described in detail in the Jungersen patent U.S. 2,380,447, issued 31 July, 1945, the Hoopman patent U.S. 4,588,258, issued 13 May 1986 and the Stamm patent U.S. 3,712,706, issued 23 January 1973 (each of which is incorporated herein in its entirety by reference.) In particular FIG. 15 of the Jungersen patent illustrates in plan view a sheet of reflective prisms which reflect light at an angle other than perpendicular to the reflector. The Hoopman patent discloses cube-corner retroreflective articles in which the optical axis of the elements in an array of prism element pairs are tilted toward one edge of the elements, when considered from the front surface of the article on which light to be retroreflected images. This tilt direction is herein defined as "positive" type tilt; as contrasted to the tilt direction shown in FIG. 15 of the Jungersen patent in which the optical axis of prism pairs tilts away from the common edge.

In the course of prosecuting an EPO patent Publication No. 0137736B1 (corresponding to the Hoopman U.S. Patent above-referenced) it was alleged that the direction of tilt in Jungersen (negative) from one perspective might seem more effective to increase the capability of cube-corner elements to reflect light through an increased range of incident angles and more specifically "to open the way to receiving into the cube corner, and thus reflecting larger amounts of light, especially in the X-X plane" of the retroreflective sheeting.

It was further alleged that the tilt direction (positive) of the Hoopman patent increases "angularity" in

both the X-X plane (horizontal) and Y-Y plane (vertical) and that this was an unexpected but desirable result especially for use in traffic control signs.

Walter, U.S. Patent No. 5,171,624 (also incorporated herein in its entirety by reference) discloses microprism reflective sheeting in which prism pairs are tilted with respect to one another at an angle of 3-10°, prism size of 0.006-0.025 (space between apices) and wherein at least one prism side surface is arcuate.

Benson U.S. Patent No. 5,122,902 discloses retroreflective cube-corner elements with separation surfaces between elements and truncated cube-corner elements.

Summary of the Invention

Contrary to the foregoing teachings in the prior art in a first embodiment of the present invention, cube-corner retroreflective articles having wide observation angle performance, uniform orientation angle performance and wide angularity in multiple viewing planes are provided by very small (0.0005 inch to less than 0.006 inch) size retroreflective elements and wherein pairs of such elements are tilted with respect to one another, preferably in a direction such that the optical axes are tilted away from each other i.e. negative type tilt. The prism elements are formed of three lateral mutually perpendicular faces defined at their bases by linear edges which do not necessarily lie in a common plane. Exceptional performance is achieved when the three mutually perpendicular reflecting faces of the prisms are coated with a thin layer of a dielectric or highly reflecting metallic coating.

Also contrary to the foregoing teachings in the prior art in another embodiment of the invention, cube corner retroreflective articles having wide observation angle performance, uniform orientation angle performance and wide

angularity in multiple viewing planes, superior whiteness properties and truer color are provided by an array of retroreflective prism elements wherein pairs of such elements are tilted in a negative direction with respect to one another and wherein windows are formed in one of the prisms of some of the prism pairs adjacent the intersection between prism pairs. The prism elements are corner cubes formed of three lateral mutually perpendicular planar faces defined at their bases by linear edges which do not necessarily lie in a common plane.

The windows are formed by casting the elements on a mold in which a section of the prism element mold is removed.

Removing a section of one of the prism mold elements creates a smaller prism element which produces increased observation angle performance. Good observation angle performance is especially important for retroreflecting objects viewed by trucks or airplanes where the source of light is spaced a further distance from the driver than an automobile. Such improved performance is also important for automobile drivers when the driver is very close to the retroreflecting object.

Brief Description of the Drawings

FIG. 1 is a plan view of a portion of a preferred embodiment the retroreflective sheeting of the invention.

FIG. 2 is a side-view of a portion of the top surface of the sheeting of FIG. 1 taken along lines I-I.

FIG. 3 is a side-view of a portion of the top surface of the sheeting of FIG. 1 taken along lines II-II.

FIG. 4 is a side-view of a portion of the top surface of the sheeting of FIG. 1 taken along lines III-III.

FIG. 5 is an enlarged plan view of a single pair 10A,10B of prism elements illustrating small prism pairs with negative tilt as in the present invention.

FIG. 6 is a side-view of the prism elements of FIG. 5 taken along lines V-V.

FIG. 7 is a dimensioned perspective view of a prior art prism structure showing the face dimensions in inches and the angular dimensions in degrees.

FIG. 8 is a sectional view taken along lines VIII-VIII of FIG. 9.

FIG. 9 is a plan view of prior art sheeting incorporating the prior art prisms of FIG. 7.

FIG. 10 is a dimensional perspective view of a prism made in accordance with the present invention showing the face dimensions in inches and angles in degrees.

FIG. 11A-11C are polar plots of the light intensity reflected from retroreflective sheeting made in accordance with the prior art.

FIG. 12A-12C are polar plots of the light intensity reflected from retroreflective sheeting made in accordance with the invention.

FIG. 13 is a sectional view of a metallized prism embodiment of the invention.

FIG. 14 is a plan view of a portion of the retroreflective sheeting of the invention.

FIG. 15 is a side-view of a portion of the top surface of the sheeting of FIG. 14 taken along lines I-I.

FIG. 16 is a side-view of a portion of the top surface of the sheeting of FIG. 14 taken along lines II-II.

FIG. 17 is a side-view of a portion of the top surface of the sheeting of FIG. 14 taken along lines III-III.

FIG. 18 is an enlarged side view of a master mold for an array of prisms illustrating how the small prisms 10C and faces 10F of FIG. 14 are formed.

FIG. 19 is an enlarged plan view of a single pair 10C/10B of prism elements of the invention.

FIG. 20 is a side-view of the prism elements of FIG. 19 taken along lines VI-VI.

FIG. 21 is a plan view of an alternate embodiment.

FIG. 22 is a side view of FIG. 21 taken along lines VIII-VIII.

FIG. 23 is a plan view of a further embodiment of the sheeting of the invention.

FIG. 24A is a plot of the intensity of light reflected from .0055 inch prism size, 3° negative tilt prism, with air backed reflector sheeting formed with no windows taken at an observation angle of 0.33°.

FIG. 24B is a plot as in FIG. 24A taken at the same observation angle with metallized sheeting.

FIG. 24C is a plot as in FIG. 24A with the addition of windows in accordance with the present invention.

FIG. 24D is a plot as in FIG. 24B with the addition of windows in accordance with the embodiment depicted in FIG. 14 of the present invention.

FIG. 25A is a plot as in FIG. 24A for relatively small 0.004 inch size prisms with 3° negative tilt and no windows at 0.50° observation angle.

FIG. 25B is a plot as in FIG. 25A at the same observation angle with metallization.

FIG. 25C is a plot as in FIG. 25A with windows.

FIG. 25D is a plot as in FIG. 25B with windows and metallization in accordance with the prism embodiment of FIG. 24.

FIG. 26 is a dimensional perspective view of a prism 10B formed in accordance with the invention.

FIG. 27 is a dimensional view of the prism of FIG. 26 modified in accordance with the invention to form a 0.0041 inch smaller prism 50 with flats 10F on all three sides thereof.

FIG. 28 is a dimensional perspective of another prism embodiment.

FIG. 29 illustrates the prism 10B′ of FIG. 28 modified to form a .0016 size prism 50′ with flats 10F′ on all sides.

FIG. 30 is a plan view of a prior art retroreflective prism mold.

FIG. 31 is a plan view of a portion of the mold of FIG. 30 as modified in accordance with the invention.

FIG. 32 is a schematic side view illustrating the different groove lines or cuts that can be taken in the second pass to make the modification shown in FIG. 31.

Detailed Description of the Invention

Referring now to FIGS. 1-6, an ultra thin flexible sheeting 100 of the invention is shown. The term "sheeting" as used herein refers to relatively thin sheet-like structures as well as thicker members, laminates and the like, which have a substantially planar front face upon which light rays impinge and which have a body portion which is essentially transparent to the light rays. The article 100 is comprised of a dense array of micro sized cube corner elements 10 arranged in pairs 10A, 10B with the optical axes 17 (the trisector of a internal angle defined by the prism faces 11, 12, 13) of the elements tilted away from one another (negative tilt). The angle of tilt β (FIG. 6) is preferably more than 1.0 degree and less than 7.0 degrees with respect to a perpendicular 19 extending from the near common plane in which the base edges of the cube corner approximate. The size of the cube corner elements 10A and 10B, in both height (h) and width (W) along with the direction of tilt, is a critical parameter for obtaining the maximum level of wide observation angle performance without sacrificing the narrow observation angle performance required for long distance retroreflective performance of the articles. Preferably the cube corner base width W1, W2, or W3 of the base is formed on a common plane in which the base edges of the

cube corner faces 11, 12 & 13 lie, and the width dimension is equal to or greater than 0.0005 inches and less than .006 inches. Optimally W1-W3 are about .002 inches.

The materials used to manufacture flexible articles 100 have indices of refraction which are preferably from 1.4 to 1.7. The thickness of the cube corner prism material is preferably a minimum of .0003 inches thick and a maximum of .004 inches thick. The total thickness of the articles is determined by the protective and bonding layers (not shown) used to manufacture the finished article. The groove angles θ and α (FIGS. 2, 3 and 4) are preferably about 73° and 65° respectively.

In accordance with the invention very small cube corner retroreflectors, especially in the base width range of from .0005 inches to .006 inches, produce diffraction effects beneficial to the desired observation angle performance of retroreflecting articles used for signs, delineators and pedestrian safety. The performance of the same articles i.e. with negative tilt and widths less than .006 inches but with Al metal vacuum deposited on the cube corner faces is enhanced. The phase and polarization changes which occur during reflection from the metallized cube corner faces at various angles of incidence and reflection produce a divergence of the retroreflected light caused by diffraction to be greater than the divergence which occurs with cube corner elements which do not have metallized faces. In addition, less light is diffracted into the secondary and higher order diffraction maximas when the cube corner faces are Al or Ag metallized. The high percentage of light (≈80%) contained in the primary maxima is uniformly distributed and the diameter of the retroreflected light pattern increases in size uniformly as the prisms decrease in size. Therefore, a smaller cube corner with metallized faces produces a beneficial effect

on observation angle performance. The negative tilt improves the wide angle performance.

The microprism sheeting 100 is conveniently formed by casting prisms upon a film surface functioning as the body, or by embossing a preformed sheeting, or by casting both body and prisms concurrently. Generally, the resins employed for such cast microprism sheeting are cross-linkable thermoplastic formulations, and desirably these resins provide flexibility, light stability, and good weathering characteristics. In some instances, the front face of the retroreflective sheeting may be provided with a protective coating such as by application of a lacquer or other coating material. Other suitable resins for the retroreflective sheeting include vinyl chloride polymers, polyesters, polycarbonates, methyl methacrylate polymers, polyurethanes and acrylated urethanes.

To protect a relatively thin body member during processing, a relatively thick carrier may be temporarily bonded thereto, and it will generally have a thickness of 0.005-0.008 inch. The adhesive used to effect the temporary bonding therebetween and which preferentially adheres to the carrier is conveniently a silicone adhesive applied to a thickness of about 0.00025-0.0005 inch. When ultraviolet curing of the resin in the prisms is employed, the adhesive must be transparent to the light rays. Although various resins may be employed for such a carrier, polyesters, and particularly polyethylene terephthalate, are desirably employed because of their toughness and relative resistance to processing conditions. As with the adhesive, the carrier should be transparent to the ultraviolet radiation used to effect curing. Moreover, the surface of the carrier may be treated to enhance the preferential adhesion of the adhesive to the surface of the carrier.

A particularly advantageous method for making such cast retroreflective sheeting is described and claimed in Rowland U.S. Letters Pat. No. 3,689,346 granted Sep. 5, 1972 in which the cube corner formations are cast in a cooperatively configured mold providing microprism recesses and are bonded to sheeting which is applied thereover to provide a composite structure in which the cube corner formations project from the one surface of the sheeting.

Another method for fabricating such microprism sheeting is described in Rowland U.S. Letters Pat. No. 4,244,683 granted Jan. 13, 1981 in which the cube corner formations are produced by embossing a length of sheeting in suitable embossing apparatus with molds having precisely formed microprism cavities and in a manner which effectively avoids entrapment of air.

The latter method has been used for forming sheeting of acrylic and polycarbonate resins which the former method has proven highly advantageous for forming retroreflective sheeting from polyvinyl chloride resins and, more recently, polyester body members with prisms of various resin formulations including acrylated epoxy oligomers.

It is customary to provide a backing sheet behind the microprisms so as to protect them and to provide a smooth surface for application of the structure to support surfaces. To effect lamination of such a backing sheet to the retroreflective sheeting, adhesives, RF welding and ultrasonic welding have generally been employed.

As previously described, the reflective interface for the prisms may be provided by a reflective coating or by an air interface. In the preferred embodiment of the present invention (See FIG. 13), a reflective coating 32 is provided upon the surfaces of at least some of the microprisms 10. Such reflective coatings have most commonly been vacuum metallized aluminum or other specular

metal deposits, although metallic lacquers and other specular coating materials have also been used.

A colored coating material (not shown) may also be provided over some of the prisms to provide a daytime coloration. Such a material may be a colored lacquer applied to the surface of the sheeting, a colored adhesive, or any other colored deposit which will coat the prism surfaces. Conveniently, a colored adhesive is employed since this will enable bonding of the backing material 34 thereto.

A retroreflective material utilizing some prisms which have reflective air interfaces and others which utilize a reflective coating offers some advantages and is described in detail in Martin U.S. Letters Pat. No. 4,801,193 granted Jan. 31, 1989. If so desired, retroreflective sheeting may be produced by applying the backing material to partially metallized materials so as to maintain the air interface in the uncoated areas.

To produce a sheeting which exhibits a daytime coloration, a colored coating may be applied over the entire area of a partially metallized surface so that it directly coats the unmetallized prisms. Thereafter, th backing material is applied. In an alternate colored embodiment using an air interface for retroreflection, a colored adhesive is applied in a pattern to the prism surface and to a depth greater than the height of the prisms. When the backing element is laminated thereto, it is spaced from the prisms by the adhesive and this provides an air interface about the uncoated prisms.

The backing material 34 may be any suitable material. For flexibility, it is a woven or laid fabric, or a flexible, durable polymeric material. Suitable resins include polyethylene, polypropylene, polyurethanes, acrylated polyurethanes and ethylene/vinyl acetate copolymers. Polyester and urethane fabrics may be employed

as well as those of natural fibers such as cotton. Flame retardants may be incorporated in the adhesives as well as in the fabric or resin backing to impart flame retardance to the retroreflective material.

Although other metals may be used to provide a specular metal deposit including silver, rhodium, copper, tin, zinc, and palladium, the preferred and most economical processes utilize aluminum vacuum deposition. Other deposition techniques include electroless plating, electroplating, ion deposition and sputter coating.

The step of adhering the backing to the retroreflective sheeting may simply involve applying an adhesive 36 to the sheeting (FIG. 13) and passing the adhesively coated retroreflective sheeting through the nip of a pair of rolls together with the backing material to apply the necessary pressure to effect adhesion. If a heat activatable adhesive is employed, the retroreflective sheeting may be subjected to preheating prior to passage through the rolls, or the rolls may be heated to achieve the necessary activation. However, it is also practicable to employ ultrasonic welding and other techniques to bond the backing material to the retroreflective sheeting by the material of the backing material itself when it is thermoplastic.

To provide a coloration to the retroreflective light at night, a dye may be incorporated in the resin used to form the body member, and even the prisms. As an alternative to a dye and as an effective necessity in some resin systems, the colorations may be provided as a finely divided pigment which is well dispersed; however, some loss in retroreflectivity will occur as the result of refraction by pigment particles which are directly in the path of light rays.

Experimental Data

In the course of developing the present invention experiments were conducted in which the sheeting of the present invention was compared to standard prior art sheeting made by Réflexite Corporation, the assignee of the present invention. Such sheeting 600 is depicted in detail in FIGS. 7-9 and is generally comprised of .006 inches cube-corner prism pairs 60A with no tilt between pairs.

By way of contrast, FIG. 10 depicts in dimensional perspective detail one prism 10B of the prism pairs 10A, 10B of FIG. 5 made in accordance with the invention.

FIGS. 11A-11C are polar plots of the light intensity (cd/lux/m^2) retroreflected from the prior art sheeting depicted in FIGS. 7-9 measured at various entrance angles (0° to 60°) and various rotation angles (0° to 360°) wherein the intensity is plotted for different observation angles from 0.1° (FIG. 11A) to 1.00° (FIG. 11C) .

FIGS. 12A-12C are similar polar plots for sheeting made in accordance with the present invention, i.e. .0050" prisms with 3° negative tilt.

A glossary of the terms used in the above referenced polar plots and Tables which follow is enclosed for the convenience of the reader.

GLOSSARY

observation angle, angle between the illumination axis and the observation axis.

retroreflection axis, a designated line segment from the retroreflector center that is used to describe the angular position of the retroreflector.

rotation or orientation angle, angle indicating orientation after rotation about the retroreflector axis.

entrance angle, this angle denotes the inclination of the object.

In comparing the two sets of plots attention is directed to the small but critical improvement in the symmetry of the retroreflected light pattern. The addition of the 3° tilt in a negative direction creates a retroreflected light distribution which is identical at both the 0° and 90° orientation angles (i.e. FIGS. 12A thru 12C versus FIGS. 11A thru 11C and Tables 1 and 2.) Also the smaller prism size causes the central maximum of the diffraction pattern to be larger thereby improving the retroreflected brightness at the .33° observation angle (See FIG. 11C versus FIG. 12C.)

Note all of the results described in FIGS. 11A-11C and 12A-12C are for arrays of cube-corner prisms formed out of acrylated epoxy, using a UV casting process. The prisms 10 are metallized with aluminum 32 on the reflecting faces (See FIG. 13). Also the front face 34 of the prisms in the array is bonded to .002" thick polyester top film 34 with a tie coat 36. Table 1 below summarizes the data collected for the plots of FIGS. 11A-11C at the 0° and 90° orientation angles and Table 2 summarizes the data collected for the plots of FIGS. 12A-12C at the 0°, 45° and 90° orientation angles. Note the lack of symmetry at 0° and 90° orientation angles present in Table 1 at most observation and entrance angles. This lack of symmetry contrasts with the near exact symmetry at 0° and 90° orientation angles that is present in Table 2 at most observation and entrance angles.

TABLE 1

Prism Size		.006	.006
Degree of Tilt		0°	0°
Orientation Angle		0°	90°
Observation Angle	Entrance Angle	Light Intensity	Light Intensity
0.10	5	2340.00	2312.00
	10	2230.00	2178.00
	20	1811.00	1666.00
	30	1267.00	1023.00
	40	690.00	460.50
	45	443.40	264.80
	50	250.70	132.60
	60	81.27	17.02
0.20	5	1228.00	1140.00
	10	1237.00	1110.00
	20	1155.00	986.90
	30	911.40	720.10
	40	546.30	377.90
	45	364.40	230.30
	50	212.40	121.00
	60	73.72	16.50
0.33	5	277.60	241.70
	10	322.90	237.00
	20	424.10	263.60
	30	466.20	298.10
	40	346.50	231.50
	45	246.60	163.40
	50	148.40	96.07
	60	59.33	15.11

TABLE 1 (Continued)

Prism Size		.006	.006
Degree of Tilt		0°	0°
Orientation Angle		0°	90°
Observation Angle	Entrance Angle	Light Intensity	Light Intensity
0.50	5	204.50	309.40
	10	201.70	258.30
	20	159.10	125.60
	30	181.40	58.71
	40	195.50	76.26
	45	151.70	75.55
	50	87.54	57.60
	60	38.67	12.38
1.00	5	74.49	39.67
	10	56.82	37.71
	20	48.18	24.69
	30	72.46	28.09
	40	24.18	22.48
	45	49.77	11.34
	50	46.85	4.63
	60	11.72	3.73
1.50	5	20.61	16.73
	10	24.33	13.90
	20	22.04	10.53
	30	10.57	11.95
	40	23.44	7.59
	45	6.89	4.71
	50	23.25	6.87
	60	9.57	1.47

TABLE 1 (Continued)

Prism Size		.006	.006
Degree of Tilt		0°	0°
Orientation Angle		0°	90°
Observation Angle	Entrance Angle	Light Intensity	Light Intensity
2.00	5	14.36	10.01
	10	12.79	8.65
	20	7.48	4.72
	30	7.15	3.99
	40	15.38	3.83
	45	10.77	6.22
	50	5.87	3.52
	60	8.50	3.20

TABLE 2

Prism Size		.005	.004	.005
Negative Tilt		3°	3°	3°
Orientation Angle		0°	45°	90°
Observation Angle	Entrance Angle	Light Intensity	Light Intensity	Light Intensity
0.10	5	3435.00	2498.00	3454.00
	10	3223.00	2375.00	3234.00
	20	2435.00	1851.00	2440.00
	30	1442.00	1149.00	1465.00
	40	628.10	539.20	658.00
	45	308.00	327.20	384.10
	50	186.00	178.50	197.20
	60	29.59	33.20	30.62
0.20	5	1938.00	1752.00	1919.00
	10	1878.00	1696.00	1888.00
	20	1596.00	1415.00	1616.00
	30	1093.00	960.40	1119.00
	40	534.00	487.20	508.20
	45	328.00	299.40	346.10
	50	171.70	168.40	183.40
	60	28.32	32.46	29.69
0.33	5	453.20	716.90	444.00
	10	491.00	740.00	488.10
	20	592.50	748.70	607.20
	30	579.30	633.70	600.80
	40	308.00	381.10	399.10
	45	250.00	249.30	268.40
	50	140.40	147.00	152.90
	60	25.23	30.38	27.15

TABLE 2 (Continued)

Prism Size		.005	.004	.005
Negative Tilt		3°	3°	3°
Orientation Angle		0°	45°	90°
Observation Angle	Entrance Angle	Light Intensity	Light Intensity	Light Intensity
0.50	5	83.18	96.41	80.71
	10	74.44	114.40	77.36
	20	88.49	188.00	96.79
	30	173.50	266.60	177.70
	40	180.70	228.30	198.50
	45	152.90	171.70	161.70
	50	97.24	110.90	106.00
	60	19.86	26.28	22.18
1.00	5	24.42	20.09	20.45
	10	20.98	30.23	19.18
	20	22.65	38.85	20.51
	30	18.91	21.75	20.95
	40	16.48	25.61	12.76
	45	20.23	31.31	17.32
	50	31.14	28.92	19.36
	60	8.04	11.45	7.71
1.50	5	9.27	8.93	8.77
	10	9.40	9.14	9.47
	20	8.98	5.68	8.30
	30	8.49	8.39	6.02
	40	6.06	7.16	4.53
	45	4.86	7.44	4.75
	50	8.07	8.23	5.32
	60	5.46	3.86	2.75

TABLE 2 (Continued)

Prism Size		.005	.004	.005
Negative Tilt		3°	3°	3°
Orientation Angle		0°	45°	90°
Observation Angle	Entrance Angle	Light Intensity	Light Intensity	Light Intensity
2.00	5	4.38	3.40	2.75
	10	4.18	4.07	2.96
	20	3.40	3.51	2.63
	30	4.31	2.64	2.88
	40	3.86	2.76	2.37
	45	3.87	2.73	1.87
	50	2.09	3.99	2.48
	60	3.52	2.66	2.64

In summary, by utilizing small cube corners in pairs with optical axes tilted away from each other by small amounts the effects of diffraction and retroreflection are combined to optimize the retroreflective pattern of light.

Utilizing very small air backed and metallized prisms for creating retroreflective articles with the above optimum retroreflective light distribution results in very thin and therefore highly durable retroreflective articles.

Referring now to FIGS. 14-20, an alternate ultra thin flexible sheeting 100 of the invention is shown. The article 100 is generally comprised of a dense array of micro sized cube corner elements 10 arranged in pairs 10A, 10B as previously filed concurrently herewith. The optical axes 17 of the elements are tilted away from one another (negative tilt). The angle of tilt β (FIG. 20) is preferably more than 1.0 degree and less than about 7.0 degrees with respect to a perpendicular 19 extending from the near common plane 16 in which the base edges of the cube corner approximate. Preferably the cube corner base width W1, W2, or W3 of the base is formed on a common plane in which the base edges of the cube corner faces 11, 12 & 13 lie, and the width or size dimension is greater than .0005 inches and preferably less than .006 inches but may extend beyond 0.006 inches to about 0.025. Optimally W1-W3 are about .004 inches.

The materials used to manufacture flexible articles 100 have indices of refraction which are preferably from 1.4 to 1.7. The thickness of the cube corner prism material is preferably a minimum of .0002 inches thick and a maximum of .004 inches thick. The total thickness of the articles is determined by the protective and bonding layers (shown in the referenced co-pending application) used to manufacture the finished article. The groove angles θ and α (FIGS. 15, 16 and 17) are preferably about 64.5° and 73.4° respectively.

So far the description of article 100 is substantially as described above in the referenced preferred embodiment. The point of departure is shown in FIGS. 14 and 19 where it may be seen that certain of the prisms 10C in a pair have at least one face 13C which is foreshortened with respect to an opposing face 13 of a prism pair. This is accomplished, as shown in the side view (FIG. 18) of a mold 110 used to make the sheeting 100 of FIG. 14.

The mold structure 110 is created by first ruling or flycutting a master from suitable material, such as, brass or copper, in three directions spaced about 56° and 62°) from one another (with the above-referenced groove angles to achieve a 3° tilt) to form three sets of grooves 22,23, 24 as shown in the partial view of FIG. 18. Then, in a secondary ruling or flycutting operation a section A of every prism in a groove is removed along line B′-B′ down to line 21 without changing the corner cubes on either side of the corner cube which is cut.

The area removed in the second pass creates a flat area 10F (See FIG. 19) and a smaller corner cube retroreflector 10C when the sheeting 100 is molded. Note that the cut that produces face 13C forms a corner cube structure 10C which has two faces (11 and 12) which are larger than face 13C. The corner cube structure 10C created with modified face 13C has an effective aperture that is slightly skewed because the line widths W_3 and W_2 are smaller by ΔW3 and ΔW2 than the original width of the prisms corner cubes, made in the first pass.

Also note that the window 10F which is created is not located in the base plane 16 of the corner cube 10C (See FIG. 20). That is, it is not bounded by the base edges of the lateral faces of the corner cube elements.

Also note that the flat area of face 10F is formed in a way which does not change the corner cube elements

immediately adjacent. Corner cube 10B is left undisturbed by the process of forming area face 10F.

Another example of removing the area on one face of a row of prisms is shown in the plan view of FIG. 21 and side view of FIG. 22.

In this example, the windows 10F are formed in the base plane 16 and the corner cubes formed have one face F1 or three faces F1-F3 modified by the second cutting pass.

Corner cube 50 has all faces modified creating a smaller corner cube.

Corner cube 52 has only one face modified creating a corner cube which has a skewed effective aperture.

The second pass ruling or flycutting shown by dotted line B'-B' in FIG. 18 and B-B in FIG. 22 can be implemented or configured in many ways. Some examples are shown in FIGS. 14 and 23. The grooves which are modified determine the number of new full smaller corner cubes 50 created; the number of corner cubes with one face modified 52; with two faces modified 54; all faces modified 50 and the direction of the corner cubes face. In the example of FIG. 23:

8 out of 70 corner cubes are untouched	11.4%
40 out of 70 corner cubes, one face is changed	57.1%
10 out of 70 corner cubes, two faces are changed	14.3%
<u>12</u> out of <u>70</u> corner cubes, three faces are changed	<u>17.2%</u>
	100%

Depending on the spacing between the grooves that are modified, the retroreflecting area can be made to have any number of windows as desired and therefore can be adjusted to provide the desired back lighting (as described below). The area of the corner cubes that is removed in the second pass, as well as the size of the corner cubes created in the first pass, can be defined to optimize window size and the retroreflected light distribution produced by the different size corner cubes which are formed. The windows

10F also have the effect of allowing adjustment of the "cap Y" or whiteness values of non-metallized and metallized retroreflections.

Experimental Data

Polar plots of the light intensity, in cd/lux/m^2, plotted at various observation angles of retroreflectors made in accordance with the invention are shown in FIGS. 24A-D and FIGS. 25A-D. FIGS. 24A and 24B and 25A and 25B are plots for 0.0055 inch and 0.004 inch prisms, respectively, without windows at respective observation angles of .33° and .50°. FIGS. 24C and 24D and 25C and 25D are similar plots for .0055 inch and 0.004 inch prism size retroreflectors with windows. The improvement in the observation angle performance at a 0.33 degree observation angle is clearly seen by comparing FIG. 24B and FIG. 24D as the cube corner size is decreased by the addition of windows. FIG. 24D shows the improvement at 0.33° observation angle for the prism configuration of FIG. 27 and FIG. 25D shows the improvement at 0.50° degrees, obtained by the embodiment of FIG. 29. However, there is a minimum prism size, i.e., about .004 inch for the first cut and about .001 inch prism size created by the second cut which produces an optimum narrow and wide observation angle result.

The above articles produce excellent entrance angle performance as can be seen by the plots in FIGS. 24C, 24D, 25C and 25D.

Tables I and II, which follow, compare the brightness in cd/lux/m^2 of .0055 inch prisms with 3° negative tilt and metal backing. In Table I, no windows have been added. In Table II, the same tooling that was used to make the sheeting in Table I was used, but windows 10F were formed

in accordance with the invention shown in FIGS. 23 and 27. The plus signs opposite certain data in Table II show where an increase in brightness occurred over the sample in Table I as a result of the smaller .0014 to .0016 prisms created when the windows were formed. Tables III and V show even better results for .004 size prisms of FIG. 29 formed in a first cut.

Orientation Angle

Observation Angle	Entrance Angle	0	15	30	45	60	75	90	105	120	135	150	165
0.10	5	2309.00	2305.00	2286.00	2279.00	2278.00	2270.00	2287.00	2312.00	2326.00	2333.00	2329.00	2319.00
	10	2166.00	2155.00	2148.00	2141.00	2157.00	2161.00	2183.00	2206.00	2223.00	2223.00	2214.00	2188.00
	20	1654.00	1654.00	1657.00	1671.00	1703.00	1743.00	1780.00	1793.00	1791.00	1780.00	1754.00	1719.00
	30	1083.00	1065.00	1049.00	1053.00	1094.00	1145.00	1172.00	1180.00	1153.00	1135.00	1138.00	1135.00
	40	585.00	551.50	509.70	502.20	521.80	553.60	583.00	577.00	549.10	536.10	562.60	604.20
	45	397.00	360.40	308.80	303.50	317.40	340.70	362.70	357.40	331.40	318.10	348.50	403.00
	50	246.90	213.90	155.30	152.90	165.90	179.60	192.40	189.10	169.40	157.20	180.30	241.30
	60	93.11	72.46	29.51	26.06	39.04	40.65	39.17	42.36	37.94	25.74	43.80	83.06
0.20	5	1409.00	1375.00	1337.00	1299.00	1288.00	1290.00	1319.00	1358.00	1402.00	1427.00	1423.00	1408.00
	10	1359.00	1327.00	1294.00	1262.00	1250.00	1261.00	1289.00	1334.00	1374.00	1391.00	1378.00	1345.00
	20	1125.00	1118.00	1108.00	1094.00	1097.00	1113.00	1140.00	1179.00	1205.00	1205.00	1168.00	1114.00
	30	754.50	767.80	787.80	788.60	798.40	830.60	853.60	881.80	878.90	867.20	837.20	778.20
	40	414.80	411.90	416.50	420.50	426.60	450.10	480.10	482.10	462.50	455.40	454.90	439.00
	45	292.60	278.60	262.60	264.20	269.10	289.80	313.50	310.60	289.10	281.90	295.00	305.90
	50	189.90	171.50	138.20	137.90	146.20	158.50	173.70	170.60	151.90	143.70	159.80	192.20
	60	80.70	63.56	27.71	24.72	36.19	37.87	37.41	40.11	35.36	24.52	41.52	73.37
0.33	5	389.90	357.50	325.60	303.70	294.00	302.20	324.40	357.10	391.00	409.20	408.90	393.20
	10	419.70	384.60	346.60	318.80	312.50	316.80	335.30	369.10	403.70	416.80	412.80	398.60
	20	453.70	432.50	401.80	377.40	374.00	367.90	370.40	417.00	456.70	450.30	421.10	403.00
	30	353.10	365.10	393.50	400.50	400.00	398.60	399.00	446.60	474.40	454.60	397.70	333.50
	40	187.80	204.30	246.50	266.40	263.90	272.20	308.80	324.70	323.80	316.00	275.20	200.20
	45	137.00	147.40	172.70	184.80	182.10	193.90	213.20	217.20	205.80	202.90	186.30	150.70
	50	101.80	103.00	105.60	109.70	111.40	121.30	136.90	135.70	120.20	117.80	119.00	110.10
	60	57.55	47.09	24.36	21.76	30.39	32.17	33.58	35.21	30.03	21.99	36.28	53.83

TABLE I

Orientation Angle

Observation Angle	Entrance Angle	0	15	30	45	60	75	90	105	120	135	150	165
0.50	5	50.17	50.25	47.86	47.95	58.51	80.81	100.50	97.25	78.85	64.34	59.76	58.64
	10	59.27	52.05	42.18	42.29	55.60	73.68	87.89	85.24	71.46	56.81	55.88	64.74
	20	116.50	83.98	41.74	37.37	52.03	54.02	51.56	59.55	64.80	50.70	53.44	92.81
	30	150.00	112.40	74.45	87.73	105.80	90.89	67.06	103.70	133.20	101.00	75.55	107.70
	40	60.67	78.46	89.98	120.20	133.30	123.30	109.90	141.80	165.50	140.00	87.60	69.23
	45	43.33	52.35	80.06	102.50	106.80	106.00	106.10	123.40	130.00	118.60	78.84	45.44
	50	28.18	36.49	60.00	70.06	70.50	74.96	84.09	87.55	81.51	80.74	62.62	33.45
	60	27.94	25.38	18.75	16.77	21.22	23.13	26.66	26.77	21.43	17.71	26.90	27.36
1.00	5	38.98	24.34	19.63	21.00	37.07	34.62	36.22	38.21	38.79	21.18	22.17	32.98
	10	47.53	25.67	19.67	24.54	37.37	40.57	37.36	40.16	37.63	24.56	21.58	36.00
	20	58.15	35.44	21.28	33.31	38.29	43.74	37.06	47.64	39.59	35.80	22.68	39.16
	30	21.92	18.47	23.09	34.16	32.91	35.81	35.15	47.26	38.43	36.77	21.26	16.40
	40	40.77	23.46	12.03	11.12	12.22	10.75	15.79	13.96	15.11	11.60	15.48	20.07
	45	30.04	20.53	7.93	12.27	28.41	17.54	8.19	16.55	33.64	12.17	11.45	18.13
	50	12.91	11.90	6.08	14.07	31.62	22.88	8.00	19.72	36.86	17.44	6.91	11.13
	60	1.89	3.60	4.66	5.52	6.02	6.82	7.56	7.92	6.96	8.16	5.88	1.94
1.50	5	36.31	10.34	8.72	10.29	24.52	18.39	12.53	18.37	30.81	11.74	8.57	15.90
	10	34.68	9.69	8.54	10.58	27.41	16.87	12.69	17.05	32.06	11.81	8.27	13.46
	20	24.45	9.93	9.41	8.55	20.73	10.94	11.79	13.17	26.16	11.58	9.49	10.80
	30	27.63	12.27	8.53	8.31	10.78	11.53	9.50	13.40	12.26	10.92	10.53	12.64
	40	12.94	9.07	5.67	8.55	15.27	13.44	4.91	13.99	16.91	9.15	7.78	9.00
	45	18.24	6.82	6.23	3.74	3.52	5.08	3.82	6.29	4.43	4.79	7.06	8.25
	50	9.04	4.56	5.81	3.27	10.33	4.81	4.49	4.04	11.75	3.66	5.30	5.14
	60	1.48	4.88	2.92	3.47	5.65	4.87	2.68	3.71	6.50	4.77	3.66	1.74

TABLE I (cont'd)

		Orientation Angle											
Observation Angle	Entrance Angle	0	15	30	45	60	75	90	105	120	135	150	165
2.00	5	17.14	5.94	5.69	5.70	10.80	9.93	6.30	11.08	13.10	6.10	5.11	7.61
	10	16.37	4.90	4.54	5.60	10.77	7.97	4.88	9.77	13.22	5.74	3.99	6.01
	20	16.09	5.31	3.23	4.73	12.30	6.84	4.69	8.21	15.39	5.77	3.55	5.80
	30	12.05	6.24	3.54	4.12	9.74	4.48	5.29	5.71	12.17	4.70	4.64	5.65
	40	7.20	4.01	4.47	2.09	6.60	4.88	4.20	3.70	6.53	2.68	5.07	3.62
	45	7.78	2.55	4.62	2.60	8.18	5.20	4.18	4.80	9.24	2.83	4.85	2.28
	50	6.60	2.65	4.22	1.48	2.19	2.80	2.50	3.20	2.85	1.87	5.38	2.27
	60	1.23	4.72	2.83	1.87	4.74	2.68	2.87	1.73	5.37	2.17	2.64	1.12

TABLE I (cont'd)

Orientation Angle

Observation Angle	Entrance Angle	0	15	30	45	60	75	90	105	120	135	150	165
0.10	5	-2097.00	-2089.00	-2074.00	2046.00	-2014.00	-1999.00	-1982.00	-1989.00	-2003.00	-2021.00	-2044.00	-2051.00
	10	-1964.00	-1956.00	-1939.00	-1911.00	-1882.00	-1860.00	-1850.00	-1856.00	-1872.00	-1879.00	-1890.00	-1889.00
	20	-1450.00	-1452.00	-1444.00	-1430.00	-1412.00	-1398.00	-1388.00	-1387.00	-1391.00	-1396.00	-1391.00	-1374.00
	30	-855.90	-856.30	-859.90	-858.30	-859.30	-863.70	-863.00	-845.60	-827.90	-818.00	-819.80	-811.80
	40	-414.50	-409.60	-399.30	-393.00	-405.00	-421.00	-423.70	-405.70	-375.60	-361.70	-377.70	-397.00
	45	-270.60	-263.10	-245.70	-239.50	-251.10	-265.50	-268.30	-252.30	-227.80	-215.10	-231.40	-259.30
	50	-171.20	-158.10	-137.40	-131.60	-140.00	-150.00	-151.20	-140.00	-123.40	-113.30	-125.90	-155.90
	60	-65.23	-56.89	+30.63	+27.20	-34.99	-36.93	-34.45	-34.03	-30.15	-21.82	-27.57	-53.64
0.20	5	-1363.00	-1339.00	-1293.00	1230.00	-1172.00	-1135.00	-1127.00	-1152.00	-1196.00	-1243.00	-1289.00	-1315.00
	10	-1301.00	-1279.00	-1233.00	-1179.00	-1131.00	-1097.00	-1093.00	-1116.00	-1159.00	-1197.00	-1221.00	-1230.00
	20	-1032.00	-1022.00	-1001.00	-977.70	-955.50	-935.70	-932.10	-948.60	-975.40	-987.00	-979.50	-962.10
	30	-664.70	-662.70	-664.80	-659.70	-658.50	-662.30	-662.80	-657.00	-650.60	-647.20	-644.30	-625.80
	40	-338.10	-338.70	-340.60	-335.90	-343.80	-358.00	-360.40	-345.50	-320.10	-311.40	-324.10	-327.50
	45	-221.40	-218.20	-213.30	-210.00	-218.10	-231.30	-234.00	-219.20	-197.00	-188.30	-204.50	-218.40
	50	-144.00	-135.20	-124.50	-121.40	-127.90	-138.00	-140.20	-129.20	-112.80	-104.80	-115.70	-136.00
	60	-58.84	-52.58	+28.78	+26.20	-33.24	-35.30	-33.39	-32.72	-28.59	-20.92	-26.53	-49.69
0.33	5	+507.60	+483.20	+431.90	+372.20	+328.70	+310.00	-315.00	-332.70	-364.10	-407.10	+454.10	+485.30
	10	+525.80	+493.90	+433.80	+381.70	+345.80	+327.30	-330.70	-351.20	-385.20	+422.30	+457.40	+487.50
	20	+528.30	+494.60	+435.30	+402.90	+392.40	+379.10	+374.00	-396.90	-428.70	-442.10	+452.00	+471.80
	30	+411.80	+396.60	+373.30	+361.80	-372.00	-370.80	-364.60	-375.90	-387.20	-384.10	-381.50	+375.10
	40	+224.60	+227.80	+237.00	-234.90	-242.50	-254.10	-254.00	-247.80	-233.60	-230.50	-235.10	+222.90
	45	+147.60	+150.20	-159.40	-160.80	-166.50	-178.30	-180.70	-170.00	-153.90	-150.80	-157.50	+153.00
	50	-97.87	-95.22	-97.57	-99.15	-103.30	-113.10	-116.30	-106.80	-92.52	-88.46	-95.76	-100.90
	60	-46.30	-44.01	+24.89	+23.59	-29.19	-31.47	-30.70	-29.65	-25.20	-18.97	-24.10	-41.58

TABLE II

+ = Area where gain occurred

Orientation Angle

Observation Angle	Entrance Angle	0	15	30	45	60	75	90	105	120	135	150	165
0.50	5	+ 145.30	+ 132.30	+ 104.20	+ 71.82	+ 67.58	+ 93.09	+ 116.70	+ 111.10	+ 87.69	+ 85.07	+ 116.30	+ 143.00
	10	+ 151.20	+ 132.30	+ 99.96	+ 70.62	+ 66.26	+ 86.15	+ 104.30	+ 101.70	+ 84.56	+ 83.47	+ 116.60	+ 147.70
	20	+ 196.20	+ 161.10	+ 106.70	+ 79.43	+ 78.32	+ 83.77	+ 85.91	+ 94.06	+ 96.43	+ 97.58	+ 126.80	+ 171.90
	30	+ 215.80	+ 177.90	+ 124.50	+ 111.70	+ 127.50	+ 125.10	+ 111.80	+ 129.70	+ 145.70	+ 139.60	+ 145.70	+ 172.50
	40	+ 130.30	+ 123.00	+ 113.70	- 116.60	- 130.90	+ 134.70	+ 122.50	- 132.00	- 136.00	- 132.10	+ 125.50	+ 118.80
	45	+ 82.16	+ 83.60	+ 89.17	- 95.88	- 104.70	+ 111.20	- 106.00	- 106.40	- 102.30	- 100.90	+ 97.07	+ 86.19
	50	+ 50.94	+ 52.56	+ 60.81	- 66.84	+ 70.79	+ 78.50	- 79.08	- 74.26	- 65.69	- 65.20	+ 65.89	+ 58.88
	60	+ 28.78	+ 30.75	- 18.57	+ 18.78	+ 22.29	+ 24.97	- 25.65	- 24.00	- 19.49	- 15.63	- 19.71	+ 29.19
1.00	5	+ 76.00	+ 32.23	+ 23.44	- 18.89	- 33.83	- 23.78	- 27.55	- 29.42	+ 38.89	- 23.17	- 23.41	+ 33.35
	10	+ 71.70	+ 33.27	- 19.17	- 18.84	- 34.75	- 23.68	- 24.03	- 27.92	+ 39.63	- 22.62	- 20.82	- 32.99
	20	+ 61.60	+ 37.57	- 14.29	- 20.14	- 33.07	- 26.00	- 20.76	- 26.87	+ 41.24	- 25.59	- 18.41	- 33.27
	30	+ 41.55	+ 27.52	- 15.28	- 21.45	+ 33.51	- 29.51	- 23.82	- 28.16	+ 38.91	- 25.53	- 19.09	+ 28.28
	40	+ 55.62	+ 31.41	- 11.93	+ 14.25	+ 20.66	+ 19.08	- 10.13	+ 15.05	+ 21.19	+ 21.05	+ 16.84	+ 27.20
	45	+ 39.98	+ 24.86	+ 11.41	+ 15.28	+ 28.44	+ 23.06	+ 8.92	+ 18.02	- 29.91	+ 25.55	+ 16.11	+ 19.16
	50	+ 16.87	+ 14.35	+ 11.13	+ 15.38	- 27.90	+ 24.30	+ 11.74	- 18.64	- 28.10	+ 24.94	+ 15.08	- 10.88
	60	+ 4.00	+ 22.31	+ 6.15	+ 6.85	+ 7.94	+ 9.80	+ 9.91	+ 8.88	+ 7.27	- 8.03	+ 8.07	+ 6.88
1.50	5	- 22.51	- 10.10	+ 11.51	- 7.19	- 13.33	- 12.54	- 11.54	- 13.40	- 15.64	- 8.46	+ 12.51	- 9.88
	10	- 23.27	- 9.31	+ 10.91	- 7.52	- 12.59	- 11.70	- 10.69	- 12.42	- 14.96	- 8.45	+ 11.47	- 9.49
	20	+ 25.02	+ 10.08	- 9.00	- 7.75	- 12.72	- 8.81	- 10.19	- 10.14	- 15.70	- 8.03	+ 9.63	- 9.91
	30	- 26.90	- 8.15	- 5.42	- 5.82	+ 12.62	- 7.09	- 7.13	- 6.31	+ 15.24	- 5.94	- 6.80	- 6.98
	40	+ 14.52	- 5.88	+ 6.02	- 5.05	- 12.32	- 7.90	+ 6.06	- 6.61	- 13.84	- 6.15	- 6.85	- 5.58
	45	+ 21.01	- 6.79	+ 6.31	+ 4.56	+ 7.36	+ 6.09	+ 5.05	- 4.95	+ 7.24	+ 6.10	+ 7.54	- 6.78
	50	+ 13.25	+ 6.46	- 5.30	+ 5.09	+ 11.67	+ 8.19	+ 3.51	+ 5.04	+ 12.14	+ 8.41	+ 6.59	+ 6.14
	60	+ 2.13	+ 39.30	+ 3.25	+ 3.67	+ 5.95	+ 5.61	+ 3.14	- 3.48	- 5.37	+ 5.70	+ 3.71	+ 3.12

TABLE II (cont'd)

+ = Area where gain occurred

Observation Angle	Entrance Angle	Orientation Angle 0	15	30	45	60	75	90	105	120	135	150	165
2.00	5	- 12.04	- 3.69	- 3.87	- 2.91	- 7.02	- 5.25	- 6.00	- 5.36	- 7.89	- 3.17	- 4.21	- 3.51
	10	- 11.38	- 3.33	- 3.34	- 3.11	- 7.07	- 4.87	+ 5.04	- 4.83	- 7.94	- 3.22	- 3.71	- 3.46
	20	- 12.58	- 4.46	- 2.50	- 3.08	- 6.05	- 4.26	- 3.25	- 4.35	- 8.05	- 3.60	- 2.98	- 5.18
	30	- 14.15	- 4.19	- 2.60	4.12	- 6.41	- 3.48	- 3.71	- 4.31	- 8.40	- 4.53	- 2.74	- 4.08
	40	- 6.88	- 2.75	- 1.98	+ 2.41	+ 6.61	- 2.80	- 1.92	- 2.25	+ 8.99	- 2.07	- 1.85	- 2.83
	45	+ 9.59	- 2.52	- 2.14	- 2.11	- 6.81	- 3.00	- 2.08	- 2.44	- 7.59	- 2.10	- 2.24	+ 2.77
	50	+ 9.49	- 2.04	- 2.88	+ 1.80	+ 3.55	- 2.14	+ 2.54	- 1.76	+ 3.53	+ 2.24	- 3.32	- 2.02
	60	+ 1.36	+ 50.40	- 2.02	+ 2.67	+ 5.06	+ 3.66	- 2.01	- 2.01	- 4.87	+ 3.58	- 2.35	+ 3.31

TABLE II (cont'd)

+ = Area where gain occurred

All values have units of cd/lux/m^2 Orientation Angle

Observation Angle	Entrance Angle (B1)	0	15	30	45	60	75	90	105	120	135	150	165
0.10	5	2536.00	2538.00	2527.00	2498.00	2469.00	2439.00	2418.00	2407.00	2411.00	2435.00	2457.00	2485.00
	10	2400.00	2400.00	2388.00	2375.00	2333.00	2308.00	2275.00	2251.00	2247.00	2263.00	2282.00	2312.00
	20	1862.00	1853.00	1851.00	1851.00	1831.00	1791.00	1748.00	1715.00	1688.00	1702.00	1712.00	1735.00
	30	1181.00	1159.00	1146.00	1149.00	1141.00	1106.00	1057.00	1039.00	1022.00	1028.00	1058.00	1101.00
	40	603.30	584.80	561.40	539.20	525.50	518.70	505.80	484.80	463.20	483.60	519.00	555.70
	45	400.60	384.40	354.30	327.20	318.00	320.20	313.20	297.90	278.00	292.10	327.30	362.10
	50	251.10	232.40	204.50	178.50	172.30	179.60	181.50	167.60	153.70	158.30	185.30	214.10
	60	90.98	96.81	47.51	33.20	36.75	40.39	39.38	38.97	35.26	29.55	42.24	72.55
0.20	5	1836.00	1837.00	1801.00	1752.00	1690.00	1627.00	1582.00	1573.00	1605.00	1663.00	1743.00	1809.00
	10	1746.00	1737.00	1724.00	1696.00	1641.00	1576.00	1516.00	1493.00	1520.00	1573.00	1639.00	1715.00
	20	1381.00	1378.00	1390.00	1415.00	1406.00	1333.00	1256.00	1230.00	1239.00	1267.00	1306.00	1366.00
	30	907.40	901.70	922.20	960.40	965.60	914.20	854.70	835.40	834.50	848.60	872.80	906.30
	40	482.80	474.50	484.10	487.20	478.60	468.90	448.20	427.90	410.40	432.50	458.10	475.00
	45	323.40	315.10	309.30	299.40	293.00	293.40	285.00	269.20	250.80	266.80	296.30	312.70
	50	207.20	197.40	184.20	168.40	163.50	169.80	172.00	157.40	143.70	150.20	172.00	188.70
	60	83.32	91.09	44.66	32.46	35.79	39.51	38.67	38.10	34.25	29.08	40.95	69.41
0.33	5	836.80	823.10	776.30	716.90	652.30	587.10	551.40	551.20	587.30	652.90	734.50	819.10
	10	817.70	802.10	763.90	740.00	689.20	610.00	550.40	552.40	598.40	656.10	726.10	819.50
	20	734.60	708.50	697.80	748.70	755.30	652.50	557.90	563.60	616.90	645.10	675.70	761.90
	30	540.60	526.40	553.70	633.70	663.30	586.20	506.20	509.20	534.30	550.60	545.10	572.20
	40	293.70	299.40	340.10	381.10	389.70	366.40	336.20	320.40	313.90	336.50	336.80	325.90
	45	200.10	206.00	231.80	249.30	249.10	245.00	231.90	217.30	204.40	222.00	229.40	217.50
	50	135.60	135.10	144.40	147.00	144.30	148.70	149.20	134.70	122.80	131.20	141.70	138.10
	60	66.25	79.21	38.47	30.38	33.21	36.80	36.51	35.45	31.37	27.26	37.01	60.94

TABLE III

All values have units of cd/lux/m^2 Orientation Angle

Observation Angle	Entrance Angle (Bl)	0	15	30	45	60	75	90	105	120	135	150	165
0.50	5	158.50	142.20	109.40	96.41	111.30	132.10	140.40	125.70	103.30	90.86	96.83	124.30
	10	197.30	164.90	119.30	114.40	123.20	119.90	113.90	110.30	111.70	108.60	108.40	142.00
	20	279.50	218.00	155.50	188.00	213.70	142.80	98.49	124.90	174.20	175.10	152.60	206.10
	30	269.20	218.00	190.30	266.60	321.30	227.50	158.90	195.80	246.20	244.60	191.90	226.00
	40	142.50	138.50	162.80	228.30	263.10	223.00	179.00	181.40	196.80	206.00	169.20	156.20
	45	88.43	95.80	127.80	171.70	185.70	171.40	149.20	143.00	142.50	154.70	133.30	111.00
	50	57.93	63.43	87.18	110.90	114.10	114.40	110.40	99.03	91.62	100.50	92.51	72.97
	60	40.98	60.49	28.04	26.28	28.26	31.73	32.03	30.32	26.00	23.66	29.35	46.82
1.00	5	68.52	57.74	35.22	20.09	29.29	33.05	28.39	24.87	30.07	26.56	37.65	77.89
	10	63.86	59.27	34.79	30.23	41.97	48.04	32.15	29.84	36.74	33.58	39.80	84.78
	20	36.52	43.92	27.91	38.85	73.34	77.59	44.49	44.51	52.44	32.94	39.42	65.45
	30	46.55	30.41	19.92	21.75	32.49	39.46	28.45	21.50	17.36	14.33	28.36	38.55
	40	72.31	41.15	13.31	25.61	62.55	25.44	8.09	22.24	47.18	31.18	11.86	33.85
	45	44.48	31.01	11.57	31.31	73.86	38.10	11.30	31.32	56.56	38.62	8.64	26.41
	50	15.69	15.36	9.55	28.92	57.34	39.87	20.20	29.98	43.91	36.07	7.96	13.29
	60	2.88	38.42	4.79	11.45	13.38	15.23	14.34	13.11	10.98	11.91	7.06	24.33
1.50	5	29.57	9.36	9.35	8.93	10.21	9.78	7.78	11.54	10.19	10.24	8.43	12.43
	10	35.19	10.34	10.19	9.14	11.52	9.46	8.23	9.22	9.16	9.77	9.29	14.75
	20	28.03	13.92	7.92	5.68	10.40	8.20	9.49	7.00	8.56	5.84	8.22	16.34
	30	17.22	12.07	7.69	8.39	30.60	15.03	6.28	14.41	28.25	11.53	7.82	12.70
	40	26.01	8.40	7.31	7.16	6.95	8.31	6.89	5.40	4.91	4.54	7.98	6.13
	45	28.67	9.31	7.50	7.44	18.27	5.56	4.22	5.06	14.65	5.16	8.88	5.81
	50	12.79	7.34	6.47	8.23	30.81	12.16	4.57	9.37	24.94	10.04	7.34	4.69
	60	1.38	45.78	2.48	3.86	8.52	7.66	3.45	5.32	7.21	6.30	1.47	32.71

TABLE III (cont'd)

All values have units of cd/lux/m^2

Orientation Angle

Observation Angle	Entrance Angle (BI)	0	15	30	45	60	75	90	105	120	135	150	165
2.00	5	19.56	4.80	3.06	3.40	6.19	3.83	3.68	4.43	5.62	3.61	3.51	5.98
	10	19.88	4.39	3.48	4.07	8.50	3.98	2.93	4.14	6.40	3.78	3.46	5.68
	20	19.05	4.91	4.03	3.51	6.07	3.49	3.54	3.37	4.80	3.25	3.75	6.03
	30	17.14	4.43	3.87	2.64	5.89	3.33	4.32	3.40	5.34	2.71	4.18	5.43
	40	5.74	3.48	4.04	2.76	14.86	6.56	2.27	4.85	12.35	4.02	3.83	3.25
	45	15.68	3.36	4.46	2.73	3.17	3.54	2.08	2.53	2.56	2.76	3.02	3.54
	50	10.74	2.86	4.30	3.99	10.10	2.35	2.99	2.24	9.06	2.08	3.37	2.35
	60	0.96	44.65	2.58	2.66	7.63	4.70	1.41	2.93	6.85	3.44	2.35	29.96

TABLE III (cont'd)

All values have units of cd/lux/m^2 Orientation Angle

Observation Angle	Entrance Angle (BI)	0	15	30	45	60	75	90	105	120	135	150	165
0.10	5	1209.00	1204.00	1196.00	1186.00	1173.00	1160.00	1158.00	1158.00	1166.00	1177.00	1195.00	1203.00
	10	1141.00	1132.00	1121.00	1114.00	1107.00	1098.00	1094.00	1097.00	1104.00	1121.00	1134.00	1143.00
	20	868.30	867.00	862.40	865.40	864.20	858.20	850.20	857.30	873.40	883.90	890.10	895.80
	30	561.10	553.40	537.00	535.10	539.30	532.80	516.70	532.80	553.50	563.60	556.40	562.10
	40	284.50	273.10	257.60	257.70	255.60	246.60	239.50	246.20	266.30	274.80	269.10	273.50
	45	184.00	171.80	157.70	156.50	155.60	148.40	145.40	150.10	161.40	169.20	164.10	169.80
	50	110.70	102.20	89.76	88.25	87.51	83.98	85.02	85.55	89.93	95.38	92.87	100.20
	60	38.46	33.86	21.53	17.83	18.97	19.86	19.50	19.85	19.75	18.63	20.59	81.92
0.20	5	874.70	876.40	854.50	824.00	790.80	763.90	748.30	751.70	770.90	800.00	827.10	853.80
	10	841.50	831.90	811.20	785.90	759.50	734.40	720.10	725.90	749.90	772.70	794.30	812.80
	20	675.00	669.60	647.10	644.50	642.50	619.60	598.40	614.80	650.10	661.50	649.90	654.10
	30	458.60	446.60	428.10	436.70	447.50	430.70	406.20	428.70	465.60	469.50	441.00	431.60
	40	240.30	229.20	218.40	227.60	230.40	218.70	210.60	218.30	243.20	249.80	230.90	224.10
	45	156.10	146.00	137.50	142.40	143.90	136.20	133.20	137.80	151.50	157.80	146.10	144.70
	50	95.25	88.01	79.84	82.24	82.67	78.96	80.15	80.58	85.19	90.91	85.42	88.51
	60	35.51	31.41	20.06	17.19	18.39	19.30	19.11	19.41	19.22	18.27	19.95	76.54
0.33	5	424.90	427.20	402.40	372.90	345.10	328.70	322.40	329.00	338.80	346.80	363.70	394.20
	10	434.70	426.90	392.80	373.20	355.90	330.70	316.30	326.30	351.20	356.50	356.80	387.80
	20	417.80	398.00	348.50	354.90	369.50	329.60	295.30	317.80	370.50	366.90	326.80	349.90
	30	320.60	300.10	263.60	288.20	313.10	282.10	247.70	271.20	326.50	320.50	263.60	262.70
	40	171.90	161.80	151.70	171.10	184.20	169.10	158.10	165.90	196.20	198.30	162.60	150.50
	45	113.70	105.60	102.50	115.20	122.60	113.00	109.30	114.00	130.40	134.30	112.10	104.00
	50	69.95	64.69	61.95	69.72	72.68	68.80	70.16	70.37	76.12	81.05	70.44	66.92
	60	29.24	26.93	17.11	15.75	17.03	17.89	18.05	18.29	18.02	17.31	18.02	67.67

TABLE IV

All values have units of cd/lux/m^2 — Orientation Angle

Observation Angle	Entrance Angle (B1)	0	15	30	45	60	75	90	105	120	135	150	165
0.50	5	142.30	148.80+	144.90+	139.90+	152.50+	193.90+	231.60+	222.00+	179.10+	142.70+	127.40+	134.80+
	10	162.30	159.00	146.60+	145.80+	150.00+	175.30+	209.00+	199.80+	168.10+	142.70+	129.20+	146.20+
	20	204.00	181.50	144.30	156.20	164.70	150.00+	158.80+	157.90+	165.30	152.80	130.00	161.50
	30	204.70	171.10	125.70	150.60	179.30	144.10	124.90	134.90	181.50	165.00	120.90	145.40
	40	119.00	105.10	85.81	105.50	131.20	109.70	96.82	103.30	139.30	132.10	91.65	92.34
	45	75.60	68.02	62.12	77.38	93.77	80.79	75.07	79.22	100.80	98.10	69.50	64.41
	50	43.14	40.26	39.78	50.78	58.25	53.33	53.82	53.93	62.06	64.39	48.16	42.24
	60	20.29	22.19	12.70	13.19	14.57	15.31	15.97	16.03	15.60	15.34	14.68	56.87
1.50	5	37.06+	18.10+	11.41+	13.78+	21.51+	20.75+	11.19+	14.09+	22.12+	12.43+	14.49+	9.62
	10	40.90+	20.43+	10.93+	11.70+	24.84+	19.65+	11.49+	13.49+	20.33+	11.59+	13.65+	11.03
	20	26.61	23.70+	10.36+	7.38+	15.80+	13.80+	10.11+	10.77+	18.85+	8.64+	9.31+	13.31
	30	25.01+	22.18+	16.95+	9.86+	17.42	14.06	8.86+	11.22-	20.74-	11.24	10.58+	12.65
	40	24.16	17.81+	9.83+	8.10+	8.87+	13.19+	7.72+	9.48+	11.68+	9.76+	7.27	13.63+
	45	25.79	14.81+	7.41	8.09+	14.24	9.35+	4.07	7.65+	12.11	9.93+	5.30	12.57+
	50	13.71+	8.65+	6.14	9.31+	16.98	9.23	5.26+	7.00	17.30	11.08+	6.42	7.00+
	60	1.16	23.79	4.01+	3.96+	4.98	4.43	3.76+	3.79	5.96	5.08	4.65+	29.02
2.00	5	14.77	6.01+	6.06+	4.74+	7.43+	6.78+	6.55+	5.43+	8.83+	5.63+	5.89+	4.37
	10	16.70	6.53+	5.57+	4.44+	8.29	5.23+	6.36+	3.90	10.91+	4.83+	5.54+	5.20
	20	19.03	8.48+	5.07+	4.39+	9.06+	5.41+	3.85+	4.13+	8.78+	3.77+	3.46-	7.28+
	30	13.19	7.33+	4.29+	3.46+	7.47+	6.26+	3.88	4.75+	9.86+	4.19+	3.24	5.60+
	40	7.36+	5.23+	4.79+	4.70+	6.93	6.35	3.99+	5.27+	12.68+	4.69+	4.56+	3.35+
	45	12.01	6.36+	4.24	3.37+	4.28+	4.95+	3.90+	3.85+	5.75+	3.49+	3.93+	4.56+
	50	8.66	4.62+	3.53	4.50+	7.81	4.83+	2.59+	3.29+	7.22	4.94+	2.72	4.46+
	60	1.75+	19.52	1.62	4.16+	3.86	2.95	2.09+	2.26	5.03	3.86+	2.47	25.24

TABLE IV (cont'd)

In summary, by forming small cube corners and window faces in prism pairs with optical axes tilted away from each other by small amounts the effects of diffraction and retroreflection are combined to optimize the retroreflective pattern of light.

Utilizing very small air backed and metallized prisms for creating retroreflective articles with the above optimum retroreflective light distribution results in very thin and therefore highly durable retroreflective articles.

Yet another embodiment of the invention will now be described in connection with FIGS. 30-32.

FIG. 30 is a plan view of a portion of a prior art mold 300 for making retroreflective sheeting. The mold is formed by ruling or machining three sets of parallel grooves 301A,301B,301C which intersect to form prism pairs P1,P2. Each prism has a base and three side walls, or facets, F1,F2,F3 which meet at an apex A. For further details refer to the prior art patents above referenced.

In accordance with the present invention, the mold of FIG. 30 is modified by a secondary ruling or machining operation as previously described in connection with FIGS. 14, 18 and 19, except that in this embodiment, portions of the prisms are removed at different levels A, B or C and/or in various thicknesses D or E, as shown in the schematic side view of FIG. 32 and the enlarged plan view of FIG. 31.

More particularly, there is shown in FIG. 31 prisms P1,P2 of various sizes depending upon the size of portions removed by the second pass of different groove depths A,B,C and/or widths D or E shown in dotted line in FIG. 32 and in solid in plan view of FIG. 31.

For example, in FIG. 31, the groove E is fairly wide, which leaves one side facet F1 much smaller than the other facets. On the other hand, the A and B grooves are not as wide, leaving the prism sides F1 and F2 of prisms P3 and P4 about the same size. Thus, depending upon the groove depth

and width of the second pass, different size prisms can be created within the same area of the mold. Compare, for example, prism P1 formed by the intersection of an E, B and an A groove, and the smaller prism P3 formed by the intersection of two wide D grooves and a C groove.

Note that some of the prism faces can remain unmodified with just the original groove 301A, B or C formed in the first pass.

Equivalents

Those skilled in the art will recognize, or be able to ascertain using no more than routine experimentation, many equivalents to specific embodiments of the invention described specifically herein. Such equivalents are intended to be encompassed in the scope of the following claims.

For example, while the preferred direction of tilt is in a negative direction; positive tilt may also be beneficial for improvement in angularity. Also, while the prism faces are shown as planar, arcuate faces may be employed for specific applications.

CLAIMS

What is claimed is:

1. Retroreflective sheeting comprising an array of reflective prisms formed into pairs of prisms, which prisms are comprised of three intersecting lateral faces which meet at an apex and wherein an optical axis of the prisms is defined by a trisector of an internal angle defined by the lateral faces; said prisms having a width dimension in the range of 0.0005 inches to less than 0.006 inches and wherein the optical axis of prism pairs is tilted with respect to one another.

2. The sheeting of Claim 1 wherein the optical axis is tilted in a negative direction.

3. The sheeting of Claim 1 wherein the angle of tilt β is in the range of about 1° to about 7°.

4. The sheeting of Claim 1 wherein the prisms are made of dielectric material and metallized on the faces.

5. The sheeting of Claim 4 wherein the dielectric material is formed of a cross-linkable thermo-plastic resin.

6. Retroreflective sheeting comprising an array of prisms formed into pairs of prisms made of dielectric material and in which the prisms are comprised of three intersecting lateral faces which meet at an apex and wherein an optical axis of the prisms is defined by a trisector of an internal angle defined by the lateral faces; said prisms having a width dimension of

about 0.0005 inches to less than 0.006 inches and wherein the optical axis of prism pairs is tilted at an angle of between 1° to about 7° in a negative direction with respect to one another.

7. A mold for forming retroreflective sheeting, the mold comprising an array of prisms formed into pairs of prisms which prisms are comprised of three intersecting lateral faces which meet at an apex and wherein an optical axis of the prisms is defined by a trisector of an internal angle defined by the lateral faces; said prisms having a width dimension in the range of 0.0005 inches to less than 0.006 and wherein the optical axis of prism pairs is tilted with respect to one another.

8. The mold of Claim 7 wherein the angle of tilt β is in the range of 1° to about 7°.

9. A method of forming retroreflective sheeting comprising the steps of:

a) forming a mold in the shape of an array of prism pairs; the prisms being comprised of three intersecting lateral faces which meet at an apex and wherein an optical axis of the prisms is defined by a trisector of an internal angle defined by the lateral faces; the prisms having a width dimension in the range of 0.0005 to less than 0.006 and the optical axis of prism pairs are tilted with respect to one another;

b) forming the retroreflective sheeting in the mold to reproduce the shape of the mold, such that, the sheeting forms prism pairs having widths in the range of 0.0005 inches to less than 0.006 inches.

10. The method of Claim 9 wherein the mold is shaped by forming a plurality of spaced apart parallel grooves intersecting at angles.

11. The method of Claim 9 wherein the grooves intersect at an angle of about 60° and optical axis is tilted by tilting the grooves.

12. The method of Claim 9 wherein the sheeting is removed from the mold and faces of the prisms are provided with a metallic film and a top non-metal film is formed opposite the faces.

13. The method of Claim 12 wherein the metallic film is formed of gold or aluminum.

14. The method of Claim 12 wherein the top film is formed of a transparent material.

15. Retroreflective sheeting comprising an array of reflective prisms formed into pairs of prisms each prism comprised of a base and three intersecting lateral faces which meet at an apex and wherein at least one of said prisms in some pairs is smaller in both height and width than the other.

16. The sheeting of Claim 15 wherein a window is formed on the shorter prism.

17. The sheeting of Claim 15 wherein the window is comprised of a surface extending from a face of the smaller prism toward an adjacent prism.

18. The sheeting of Claim 15 wherein the prisms are made of dielectric material and the prisms are tilted in a

negative direction at an angle of tilt β in the range of greater than zero to 10 degrees.

19. The sheeting of Claim 15 wherein the smaller prisms have a width dimension in the range of about 0.025 to less than .0005.

20. The sheeting of Claim 16 wherein the window extends from the base of the smaller prism to the base of the larger prism.

21. The sheeting of Claim 17 wherein the surface is planar.

22. The sheeting of Claim 17 wherein the surface is arcuate.

23. The sheeting of Claim 15 wherein the window extends from a plane above the base of the smaller prism.

24. Retroreflective sheeting comprising an array of reflective prisms formed into pairs of prisms made of dielectric material and in which the prisms are comprised of a base and three intersecting lateral faces which meet at an apex and wherein an optical axis of the prisms is defined by a trisector of an internal angle defined by the lateral faces; said prisms having a width dimension of about 0.005 inches and wherein the optical axis of prism pairs is tilted at an angle of between greater than zero and 10° in a negative direction with respect to one another and wherein at least one of the prisms is smaller than the other and wherein a flat window is provided on a face of the smaller prism.

25. The sheeting of Claim 24 wherein the window extends from a plane above the base of the prism.

26. The sheeting of Claim 24 wherein the smaller prisms have a width dimension in the range of about 0.025 to less than .0005.

27. The sheeting of Claim 24 wherein the window extends from all faces of the smaller prism.

28. A method of forming retroreflective sheeting comprising the steps of:

a) forming a mold by:

(i) forming three parallel sets of grooves in a body of mold material; the grooves intersecting at an angle to form a plurality of prisms each prism having a base and three intersecting lateral faces which meet at an apex;

(ii) removing a portion of at least one face of a prism to form a smaller size prism adjacent a larger size prism;

b) forming said sheeting in said mold; and

c) removing the sheeting from the mold.

29. The method of Claim 28 wherein the prisms are formed in pairs and the optical axis of pairs of prisms are tilted in a negative direction.

30. The method of Claim 28 wherein the step of removing also forms a window extending from said face of said smaller prism.

31. The method of Claim 28 wherein the window is formed above the base of the prisms.

32. Retroreflective sheeting formed by the method of Claim 28.

33. The method of Claim 28 including the step of metallizing the sheeting on a prism face side.

34. The sheeting of Claim 24 wherein the prism faces are metallized.

35. The method of Claim 28 wherein the portion is removed by forming an additional groove adjacent at least one of said sets of grooves.

36. The method of Claim 35 wherein the depth of the portion removed by the additional groove varies among the sets of grooves.

37. The method of Claim 35 wherein the width of the portion removed by the additional groove varies among the sets of grooves.

38. The method of Claim 35 wherein both the depth and width varies among the sets of grooves.

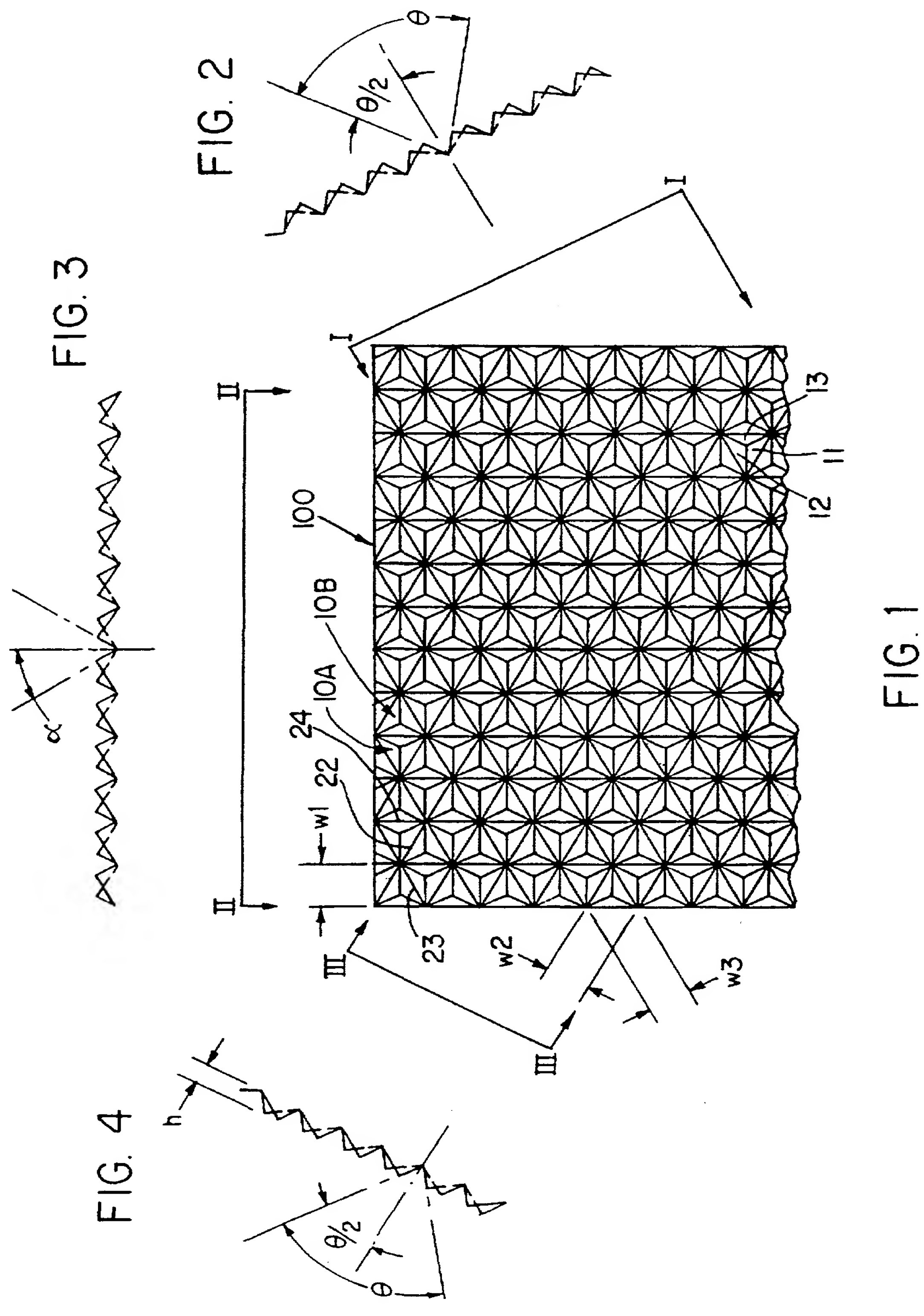


FIG. 1
FIG. 2
FIG. 3
FIG. 4
I
II
III
100
10A
10B
11
12
13
22
23
24
w1
w2
w3
h
θ
θ/2
α

FIG. 5

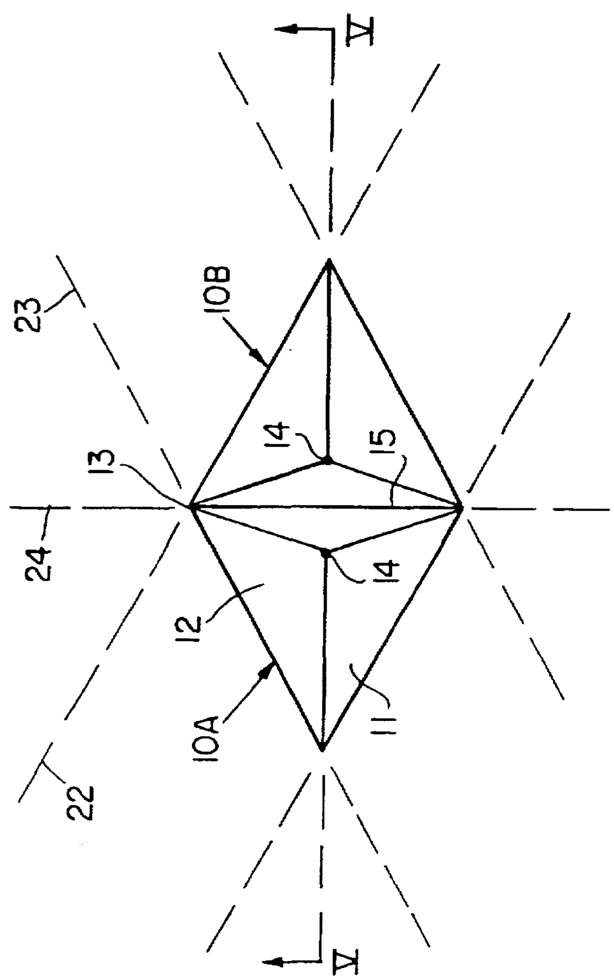
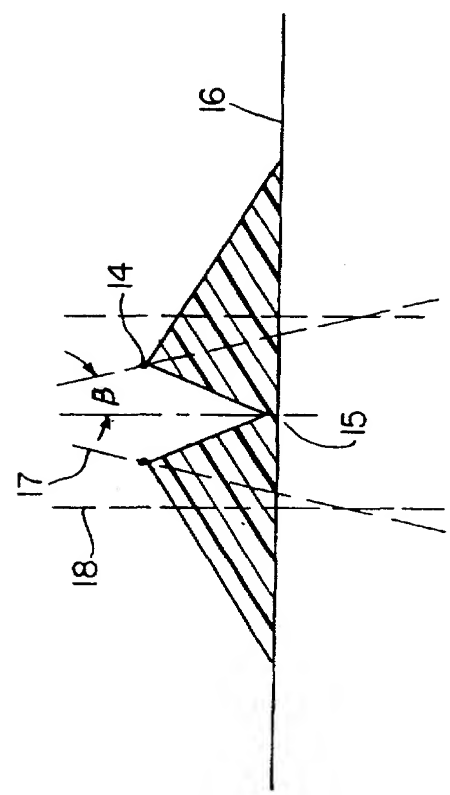


FIG. 6



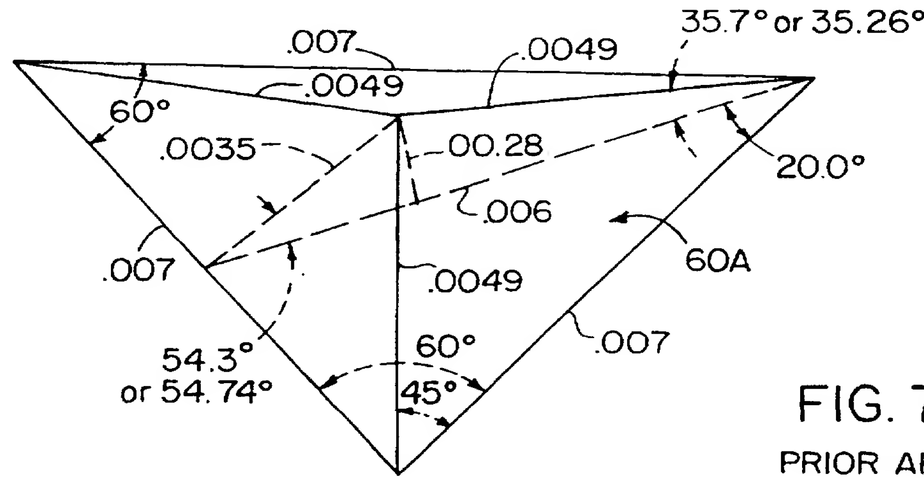


FIG. 7
PRIOR ART

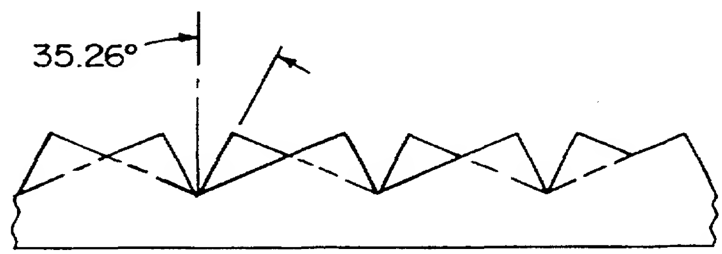


FIG. 8
PRIOR ART

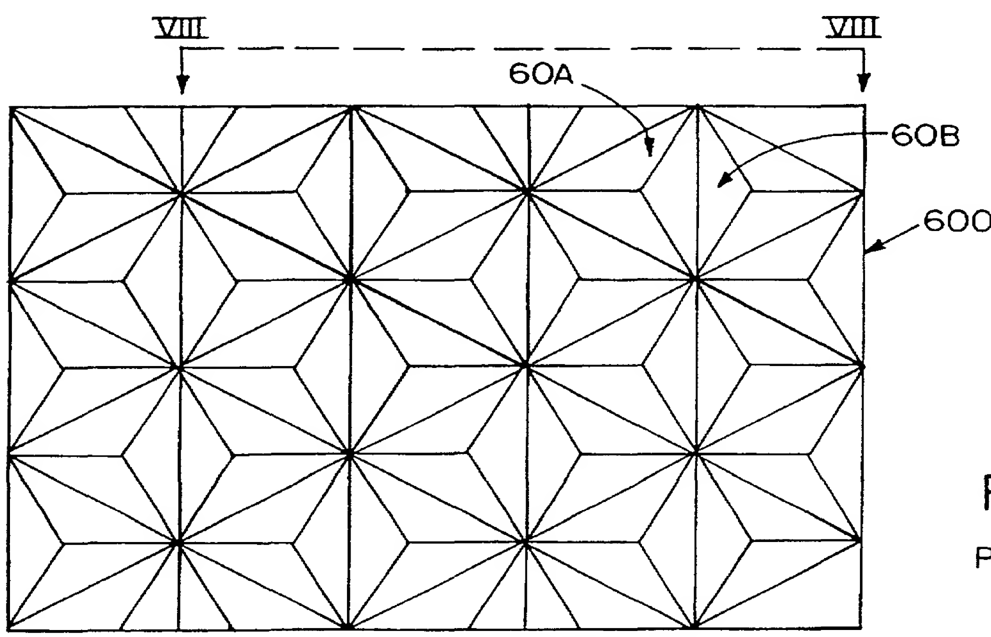
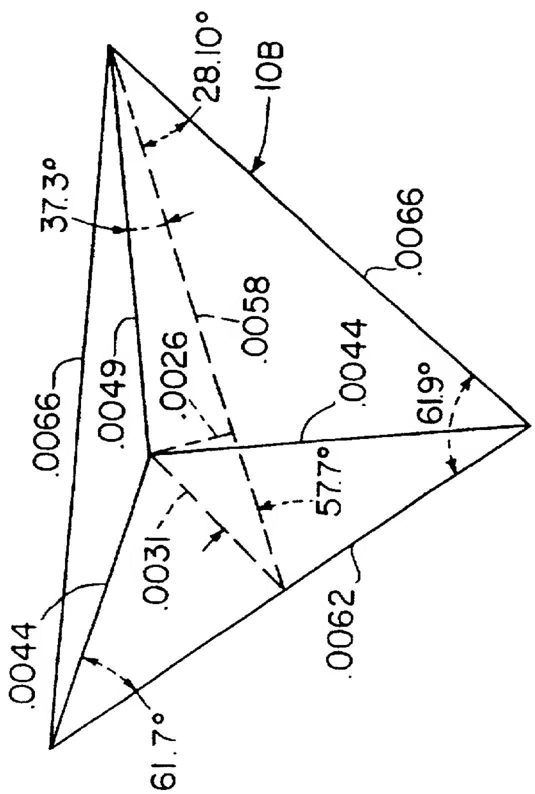


FIG. 9
PRIOR ART

FIG. 10


28.10°
10B
37.3°
.0066
.0058
.0049
.0026
.0044
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.0066
57.7°
.0031
.0044
.0062
61.7°

FIG. 13

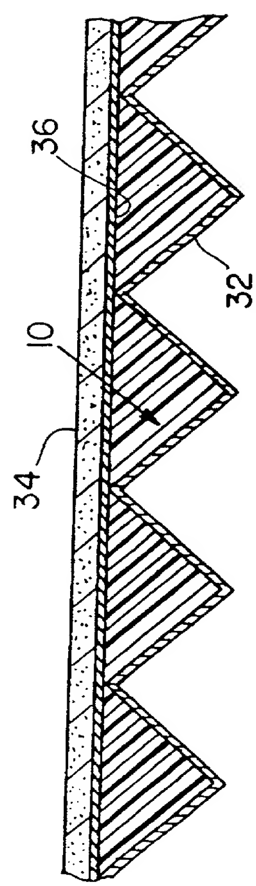

36
32
10
34

FIG. 11A

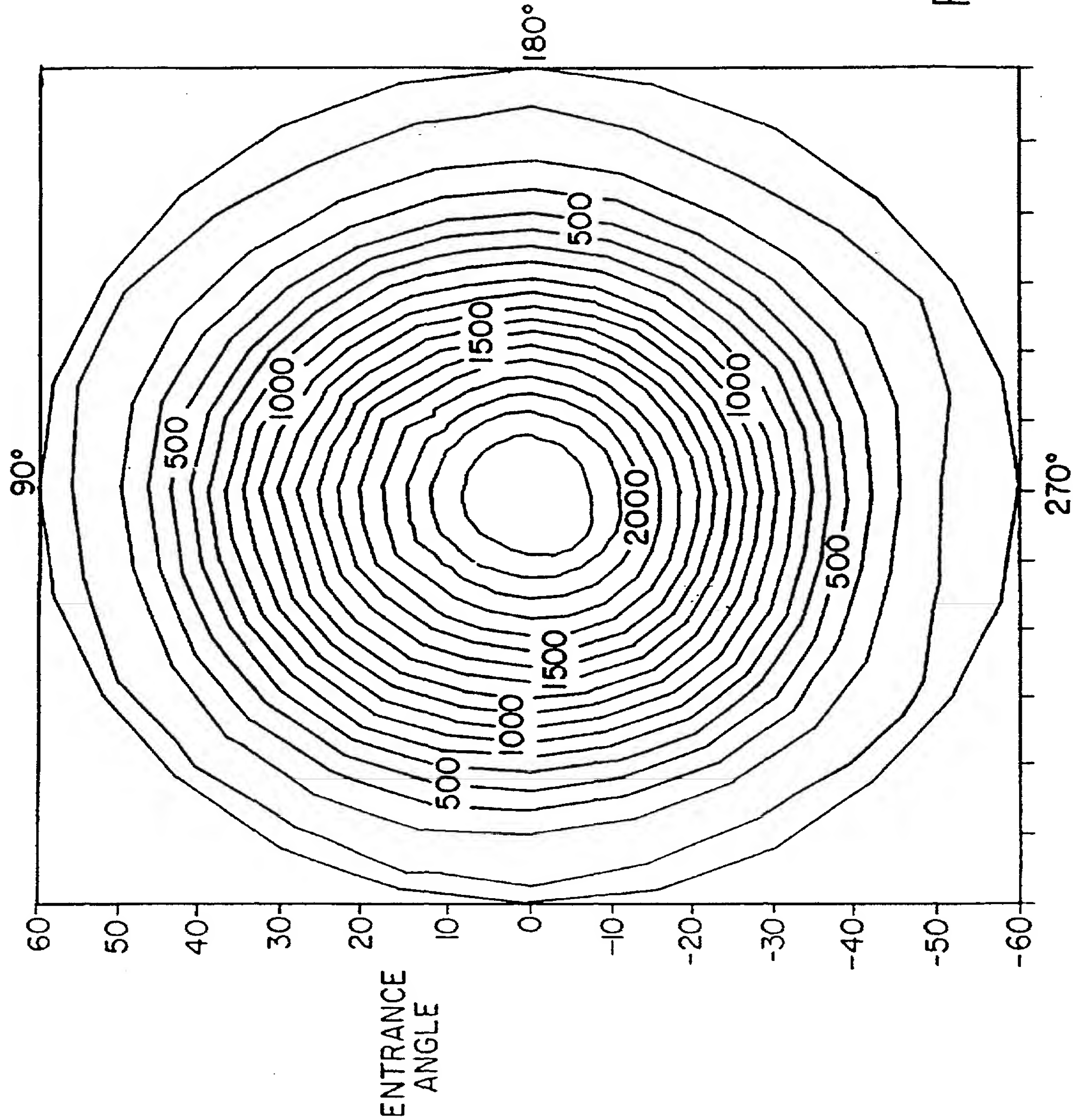

180°
90°
270°
500
1000
1500
2000
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
ENTRANCE ANGLE

FIG. 11B

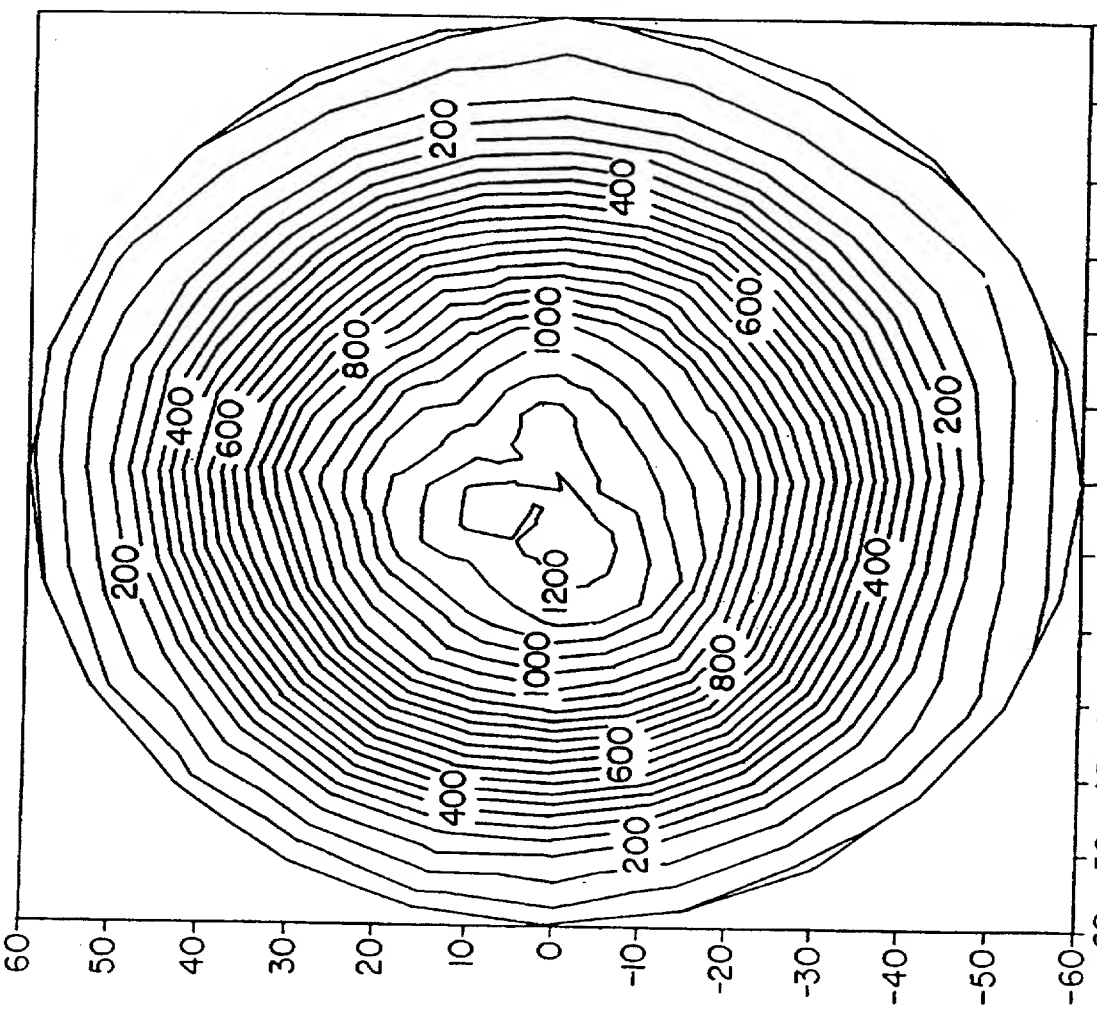


FIG. 11C

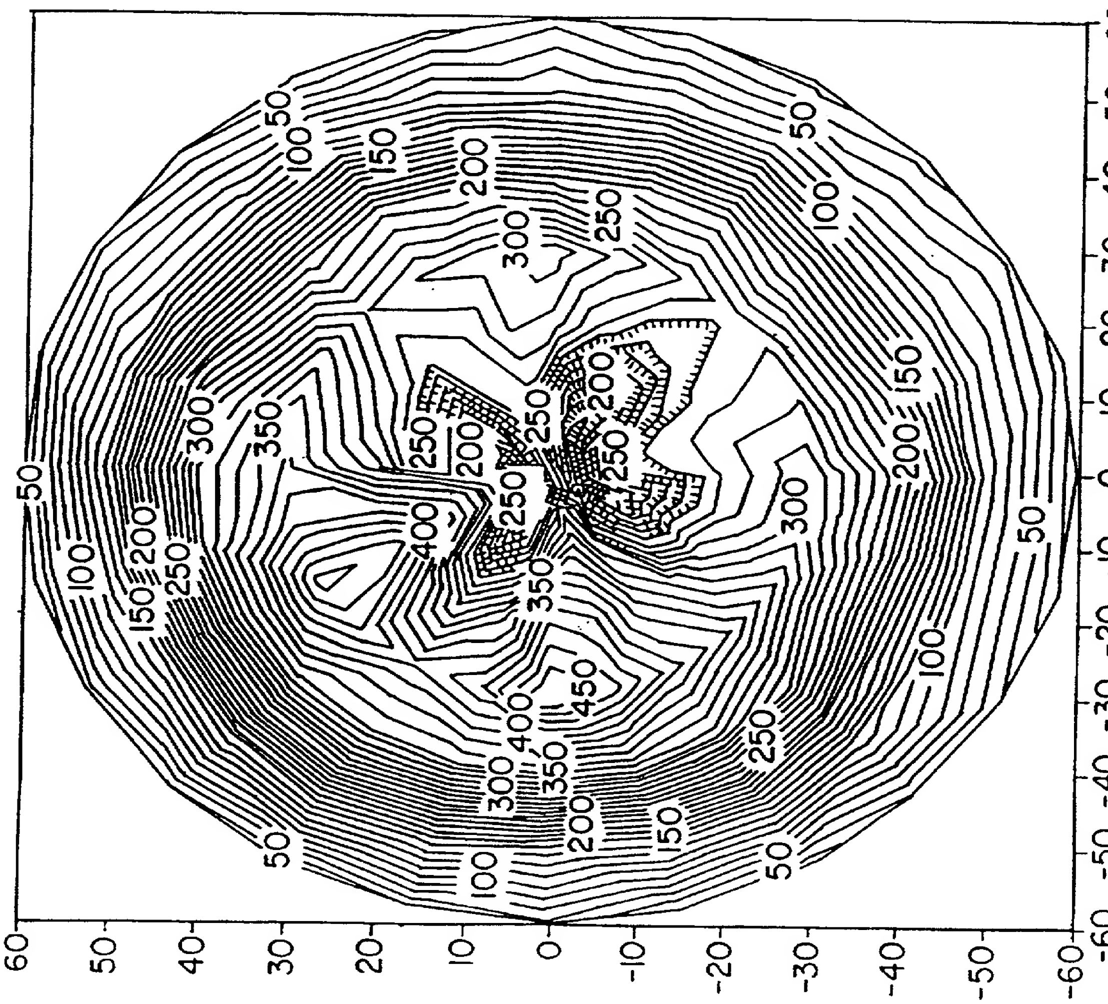


FIG. 12A

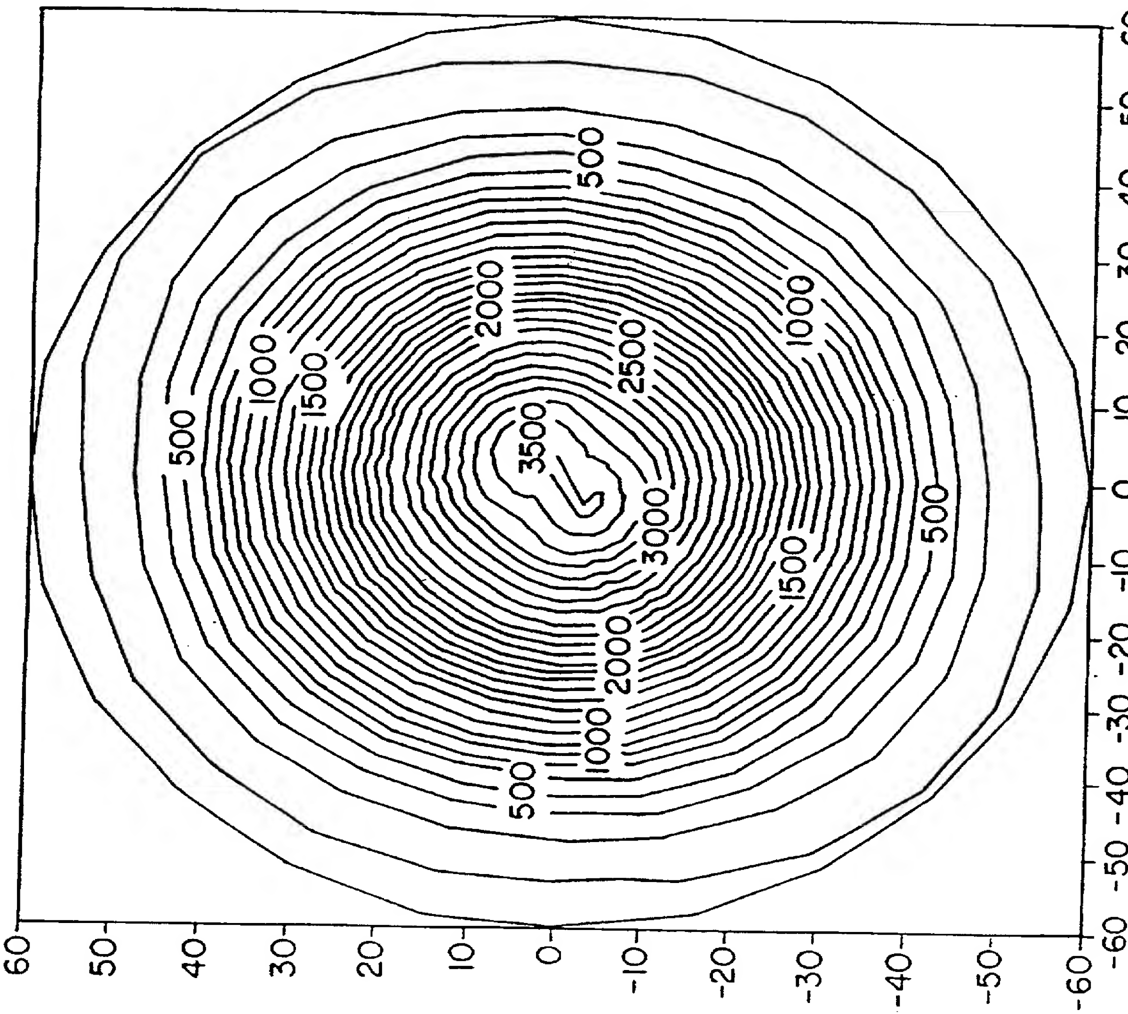
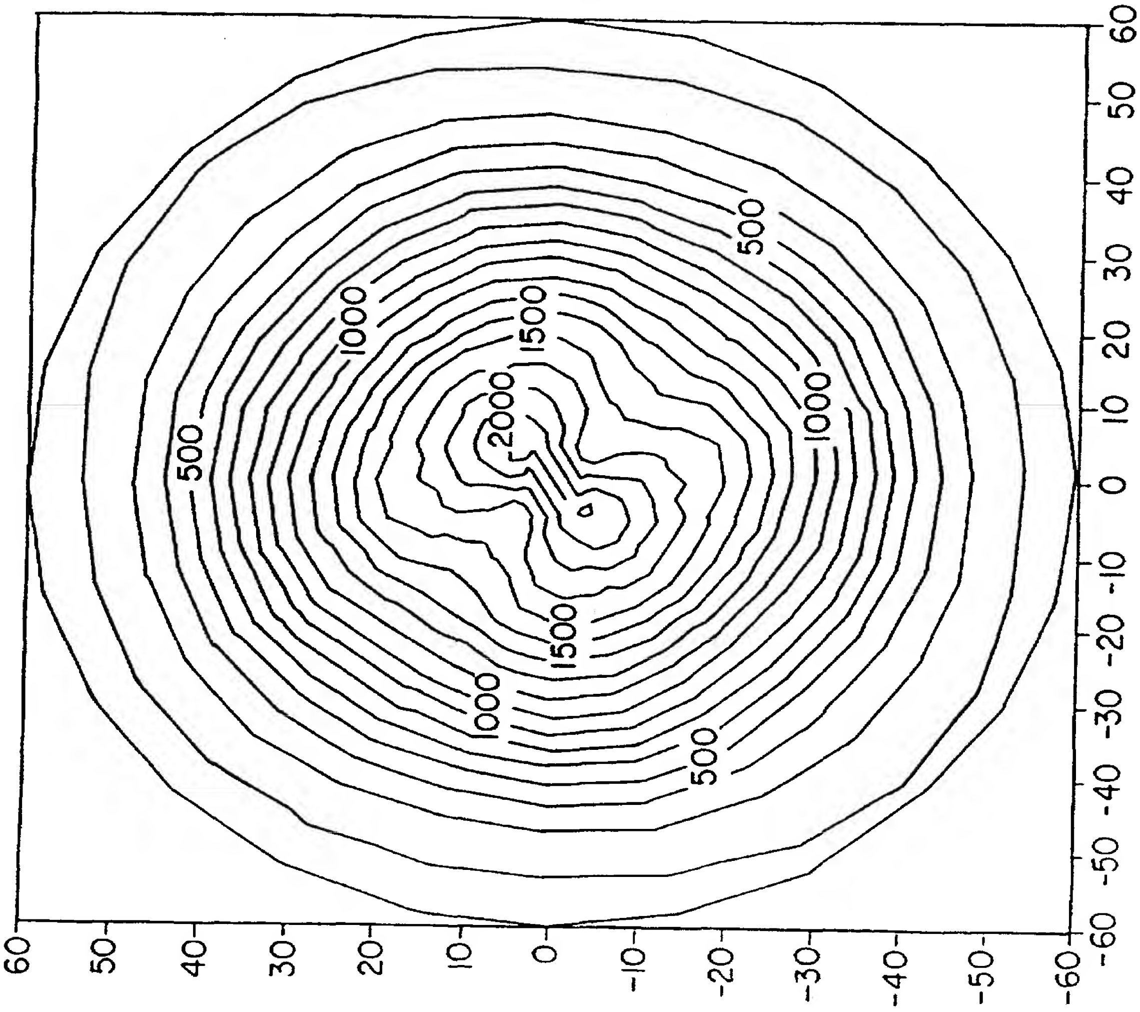

500
1000
1500
2000
2500
3000
3500
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60

FIG. 12B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1000
1500
2000
1500
1000
500
1000
1500
1000
500
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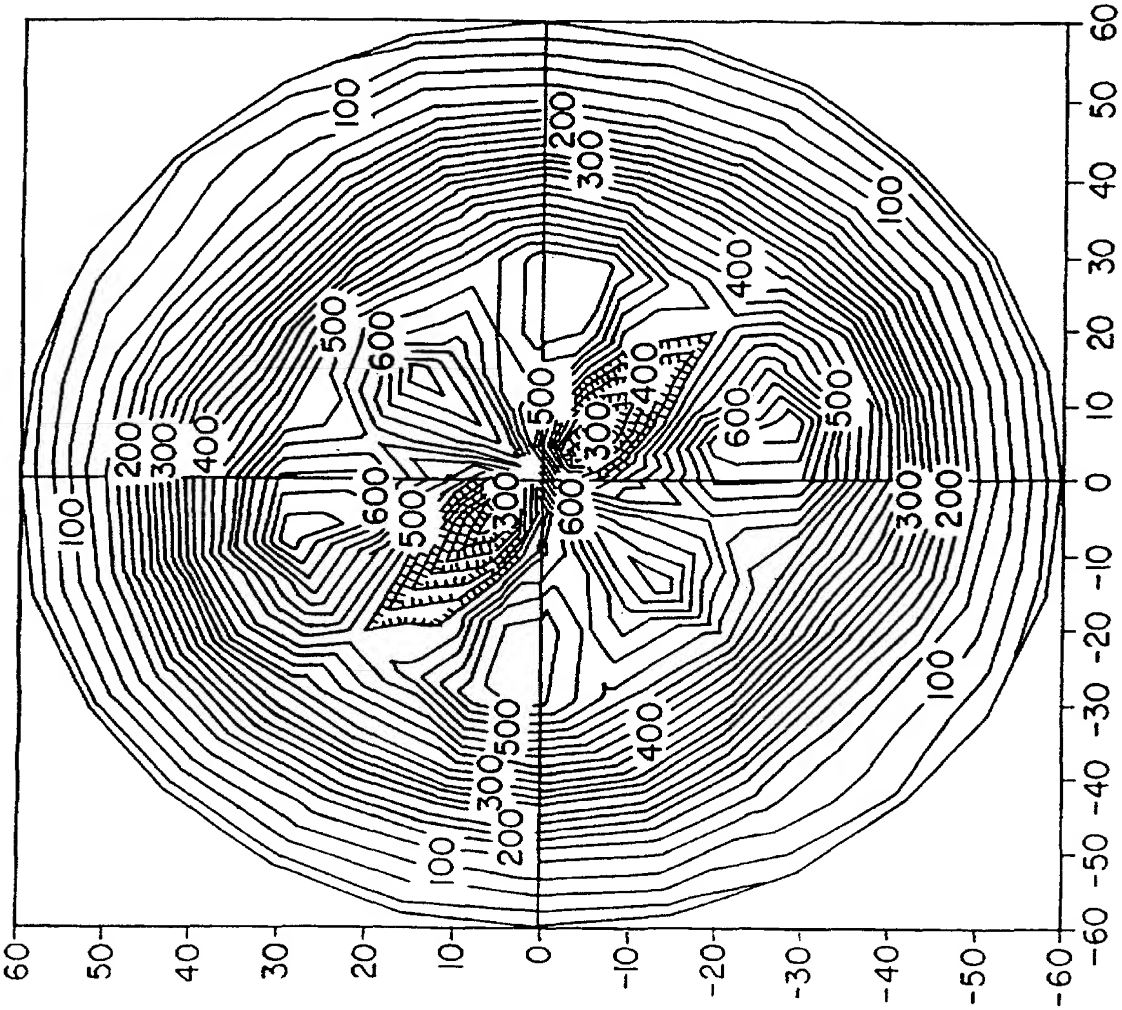
60 50 40 30 20 10 0 -10 -20 -30 -40 -50 -60

FIG. 12C



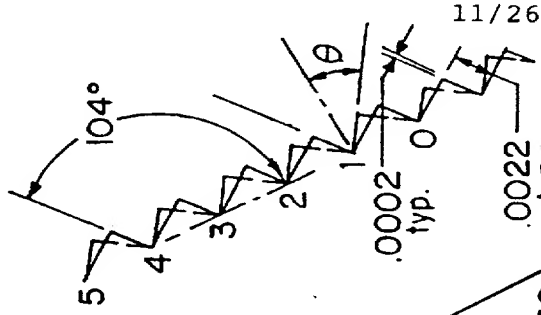


FIG. 15

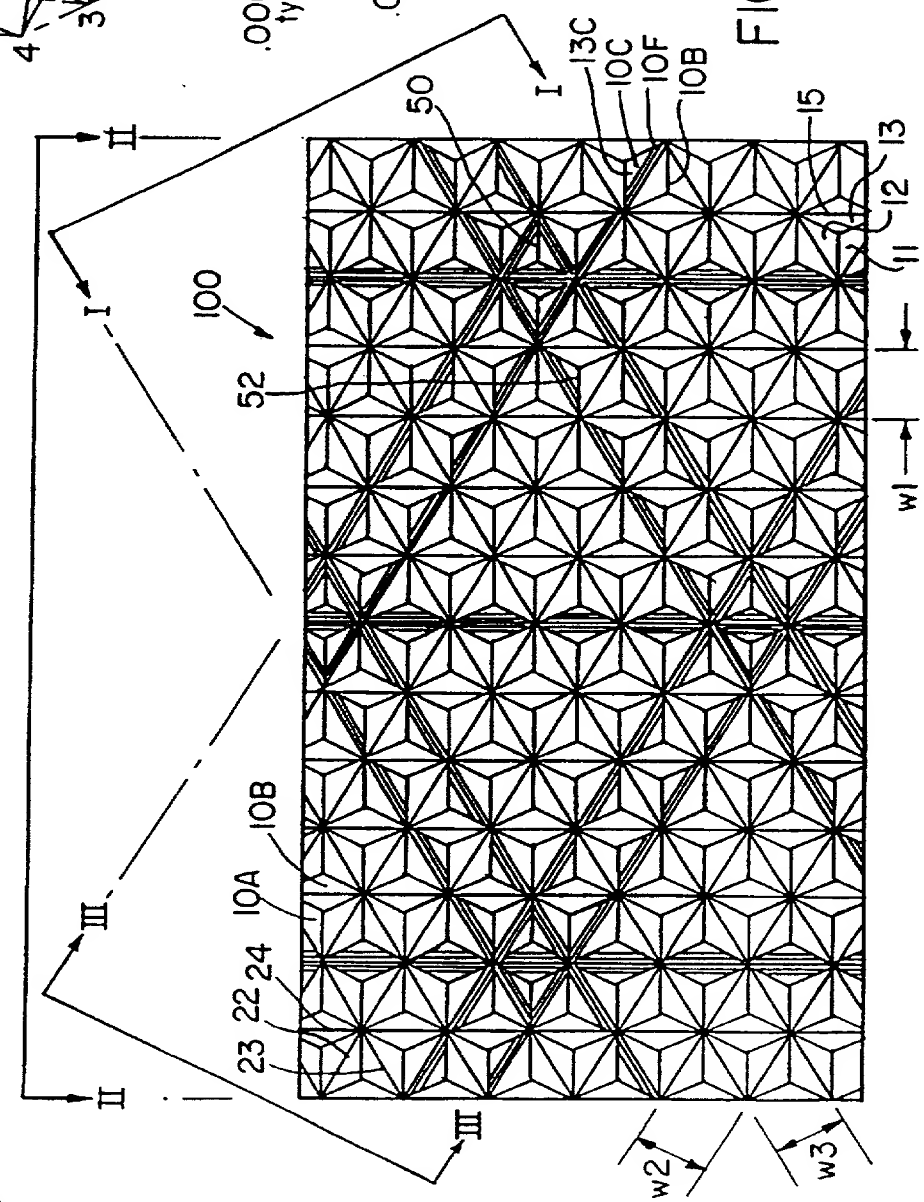


FIG. 14

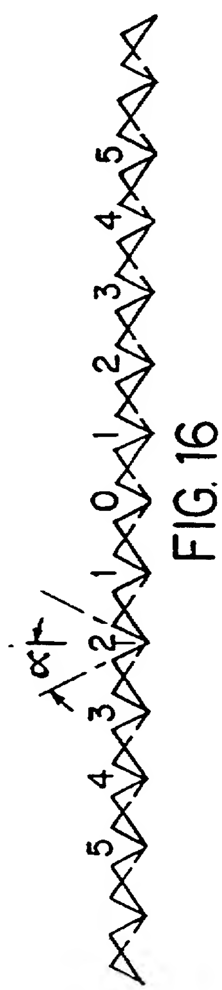


FIG. 16

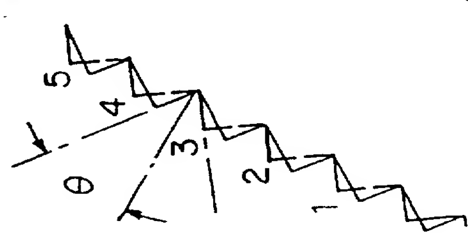


FIG. 17

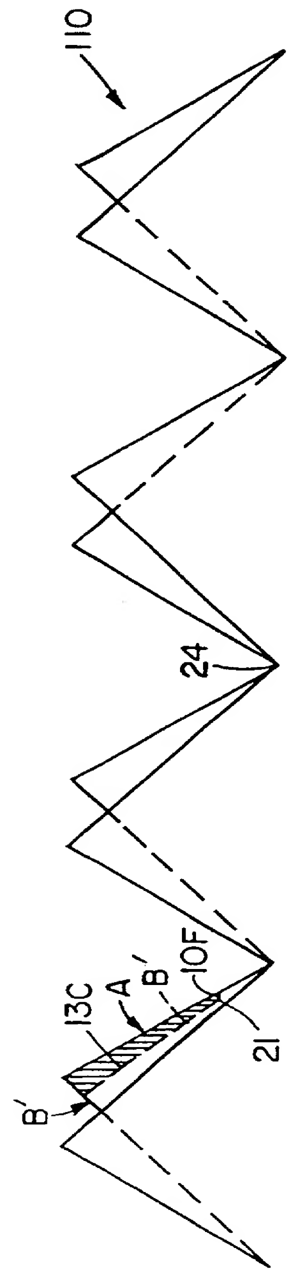


FIG. 18

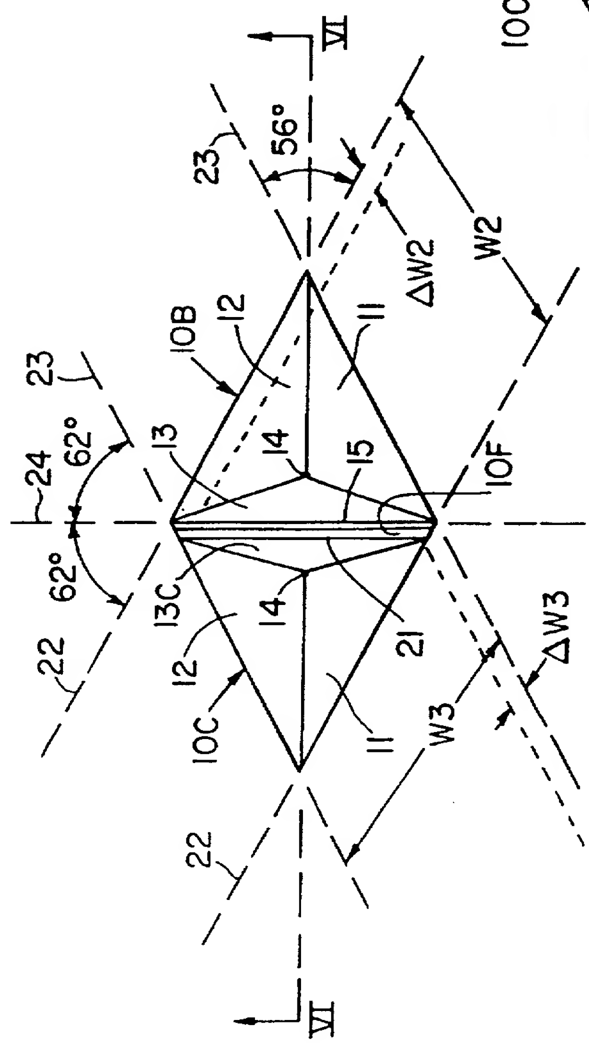


FIG. 19

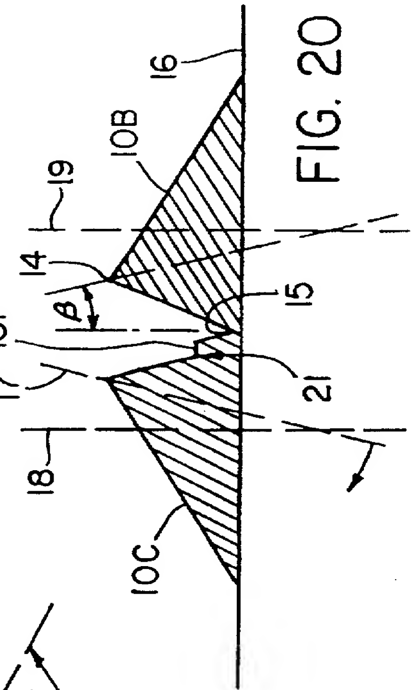


FIG. 20

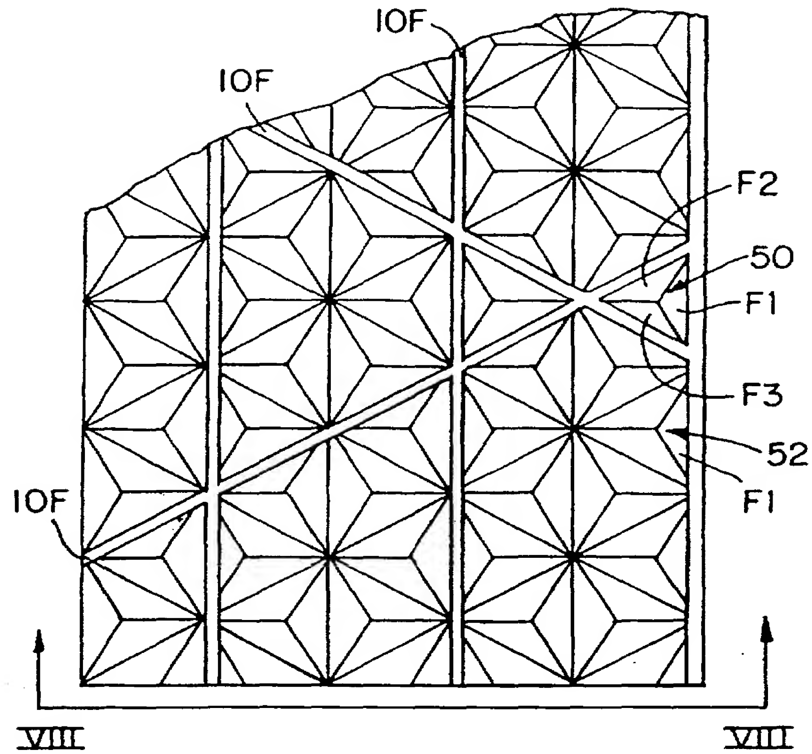


FIG. 21

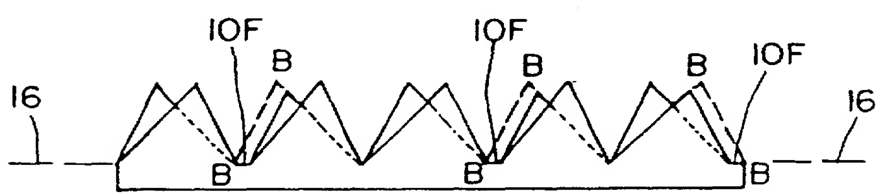


FIG. 22

FIG. 23

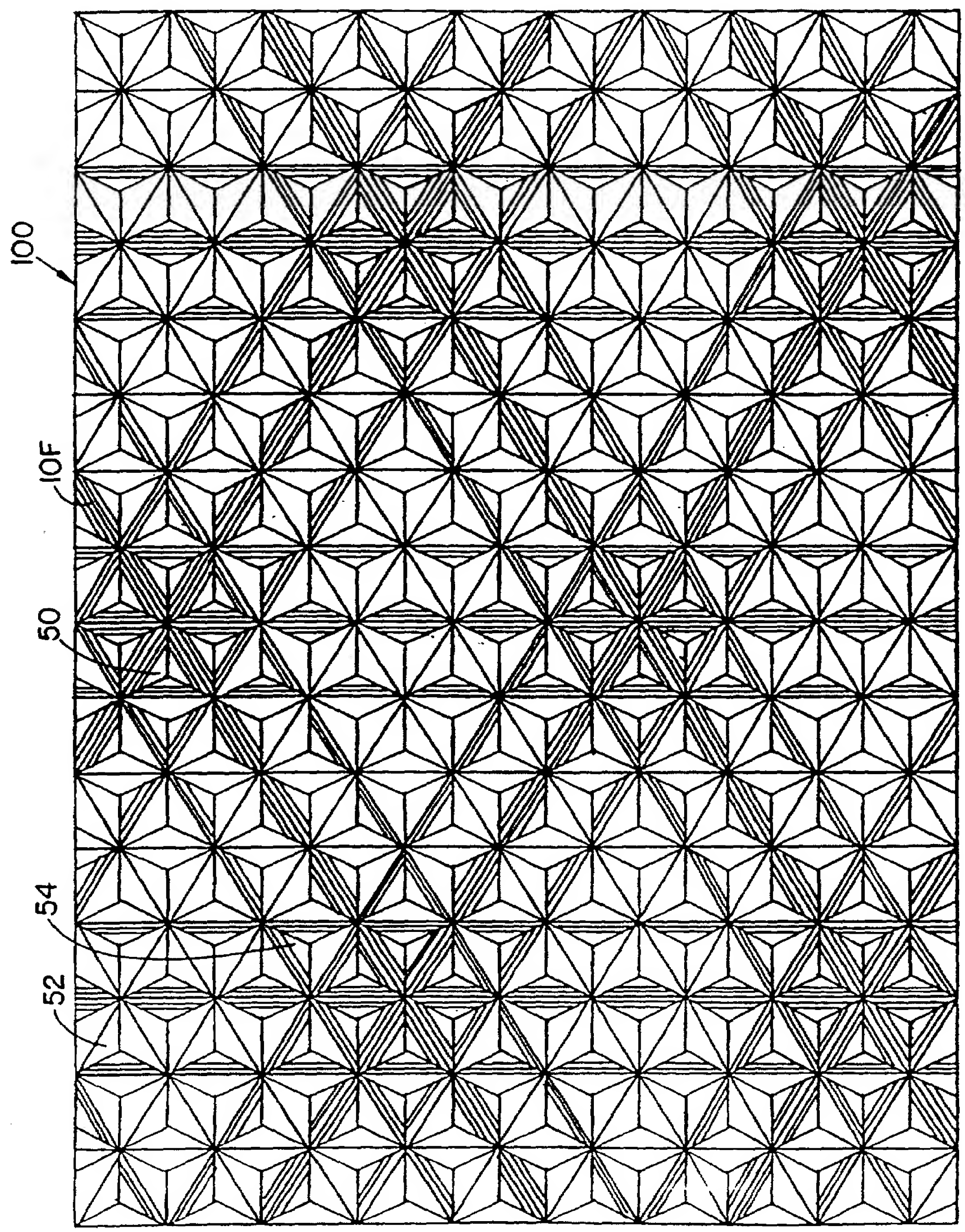
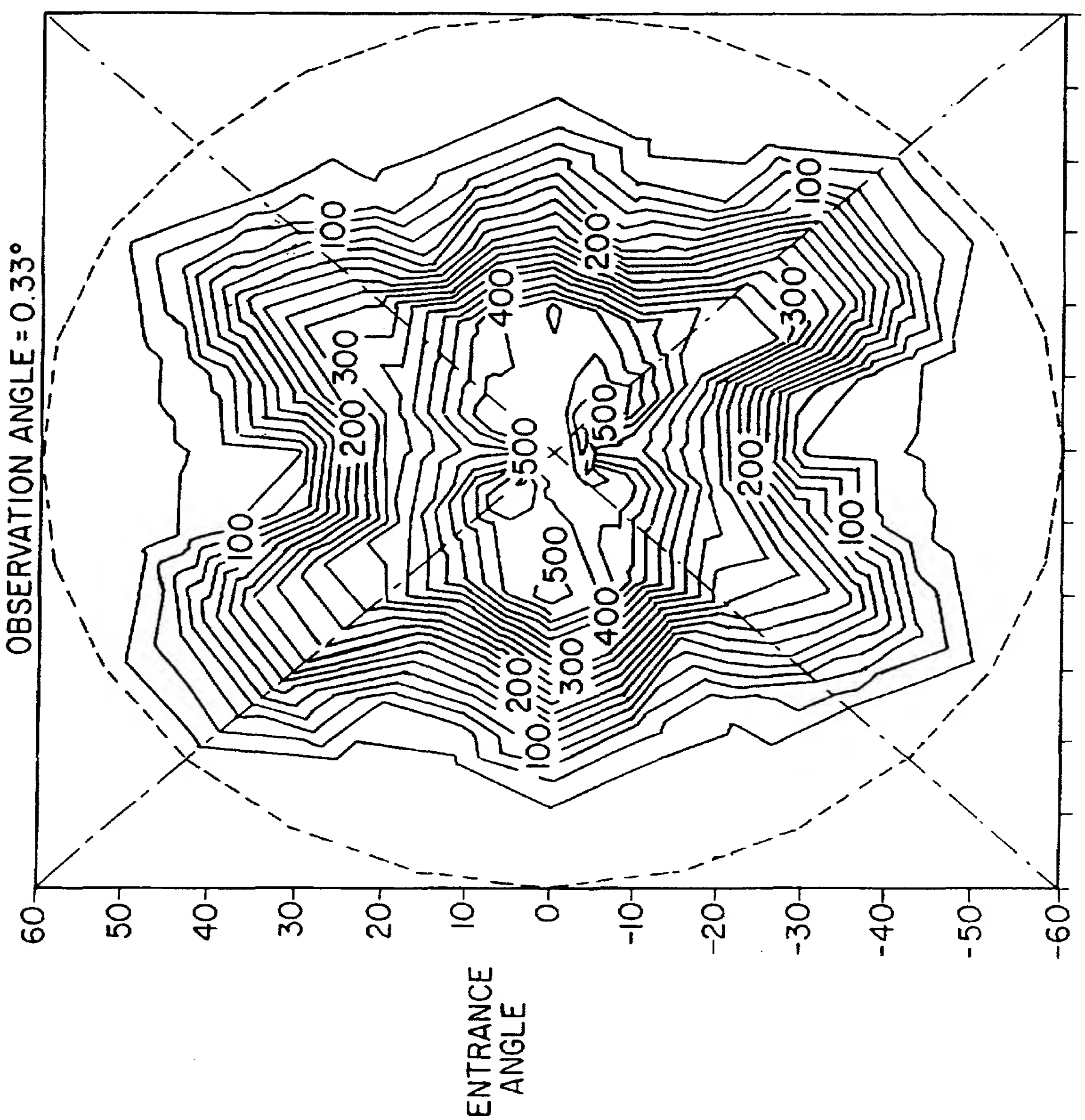


FIG. 24A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ENTRANCE ANGLE
60
50
40
30
20
10
0
-10
-20
-30
-40
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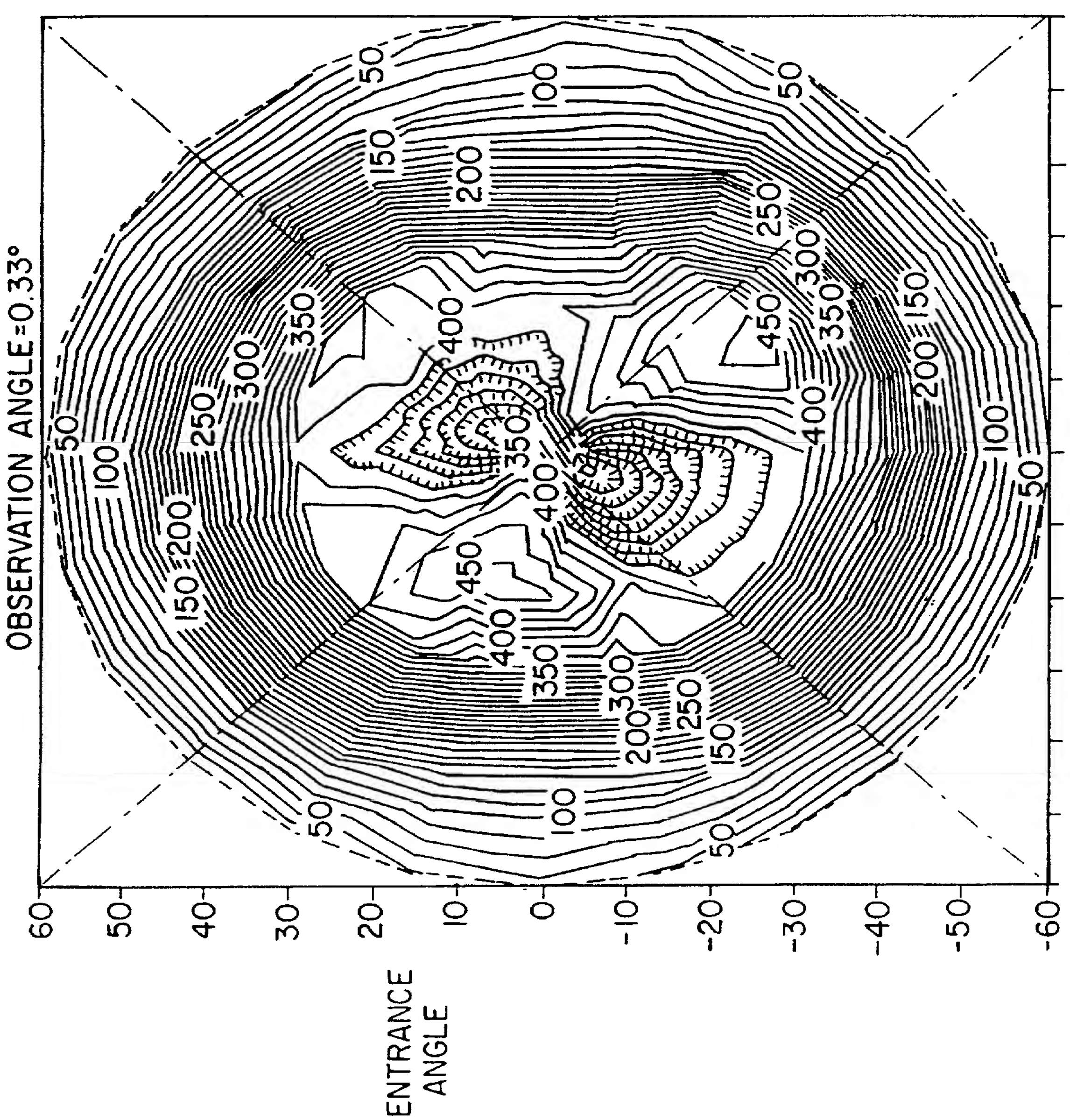
-60
100
200
300
400
500

FIG. 24B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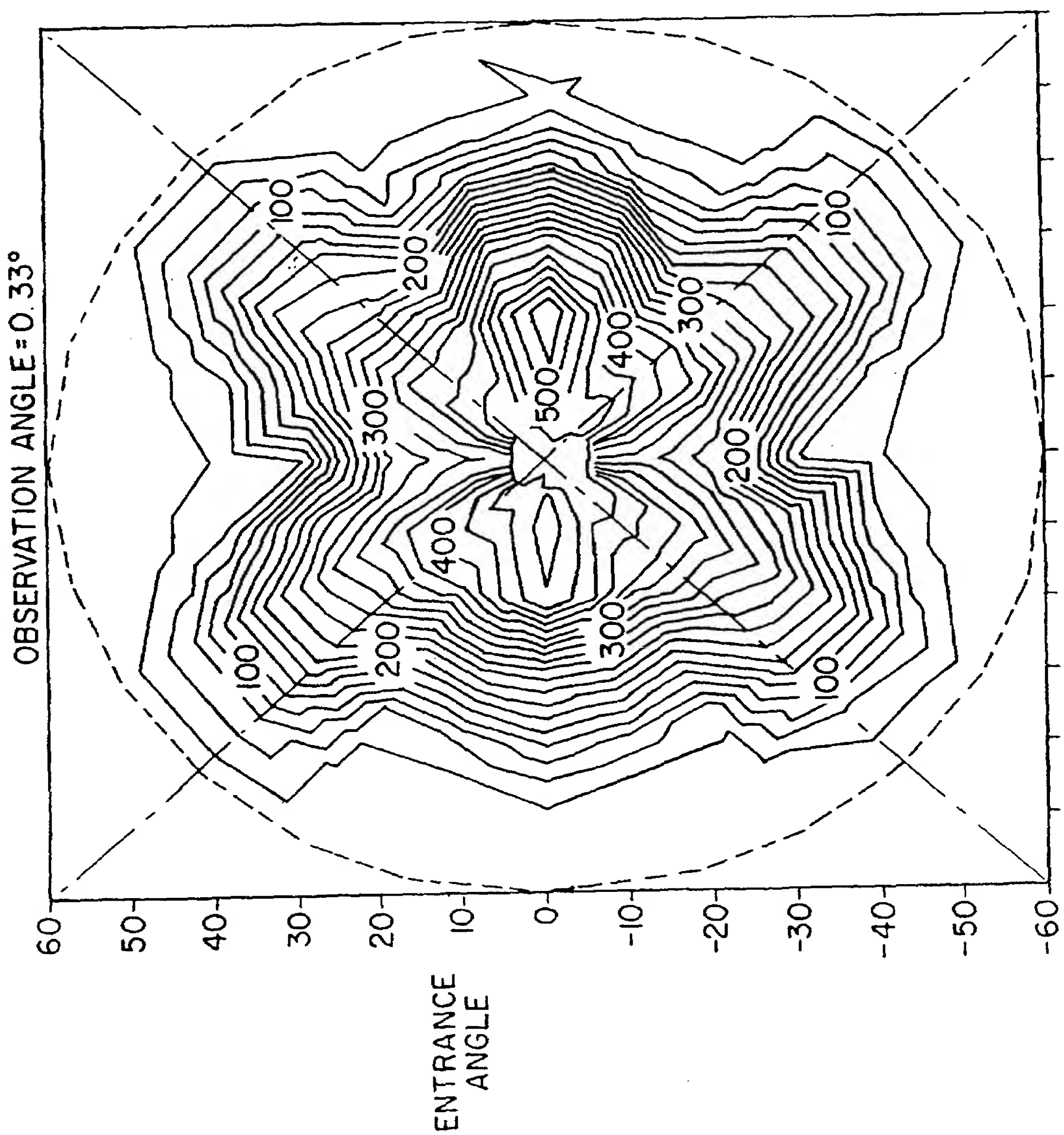
-60

FIG. 24C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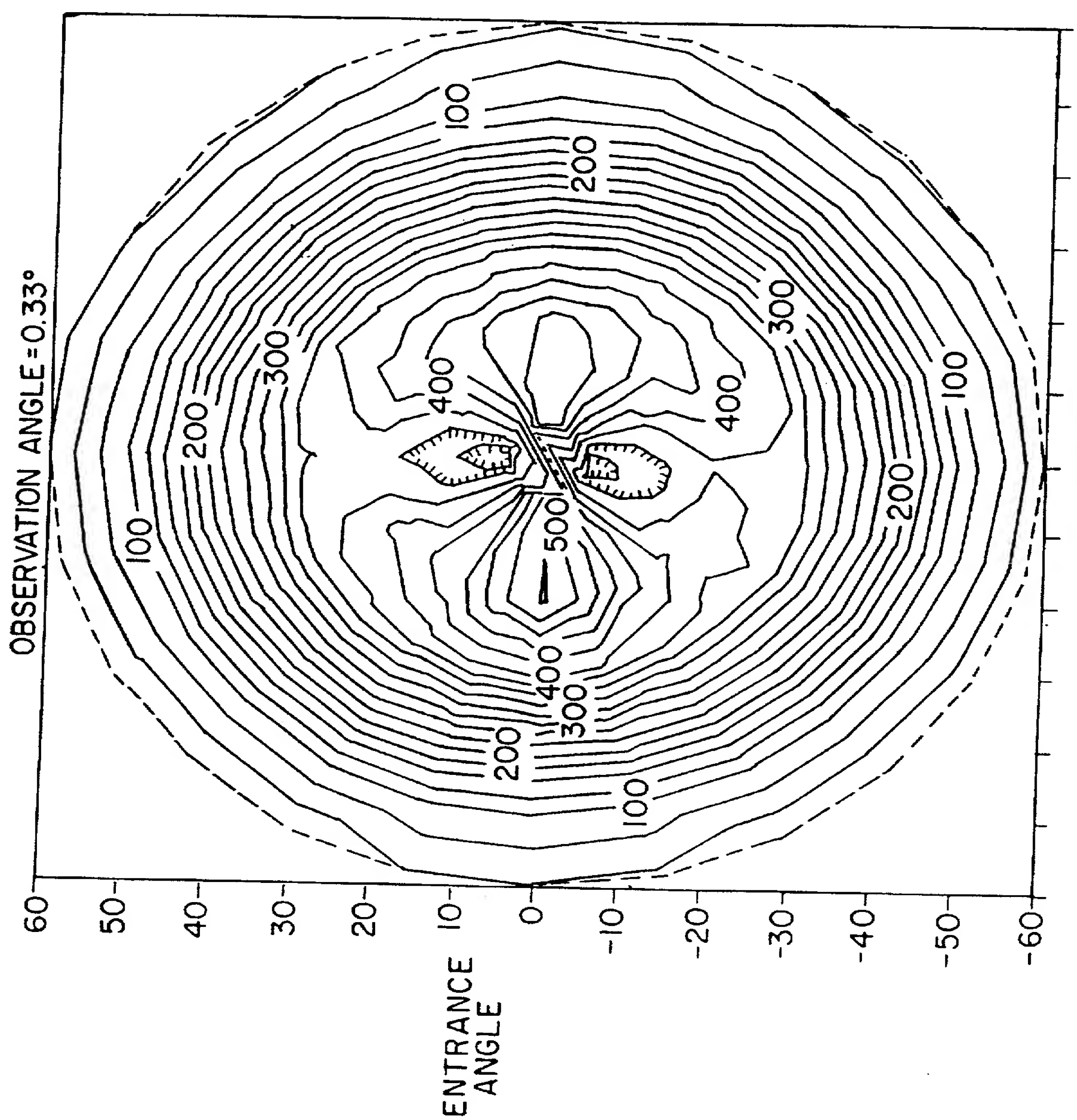
400
500

FIG. 24D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ENTRANCE ANGLE
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50
40
30
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0
-10
-20
-30
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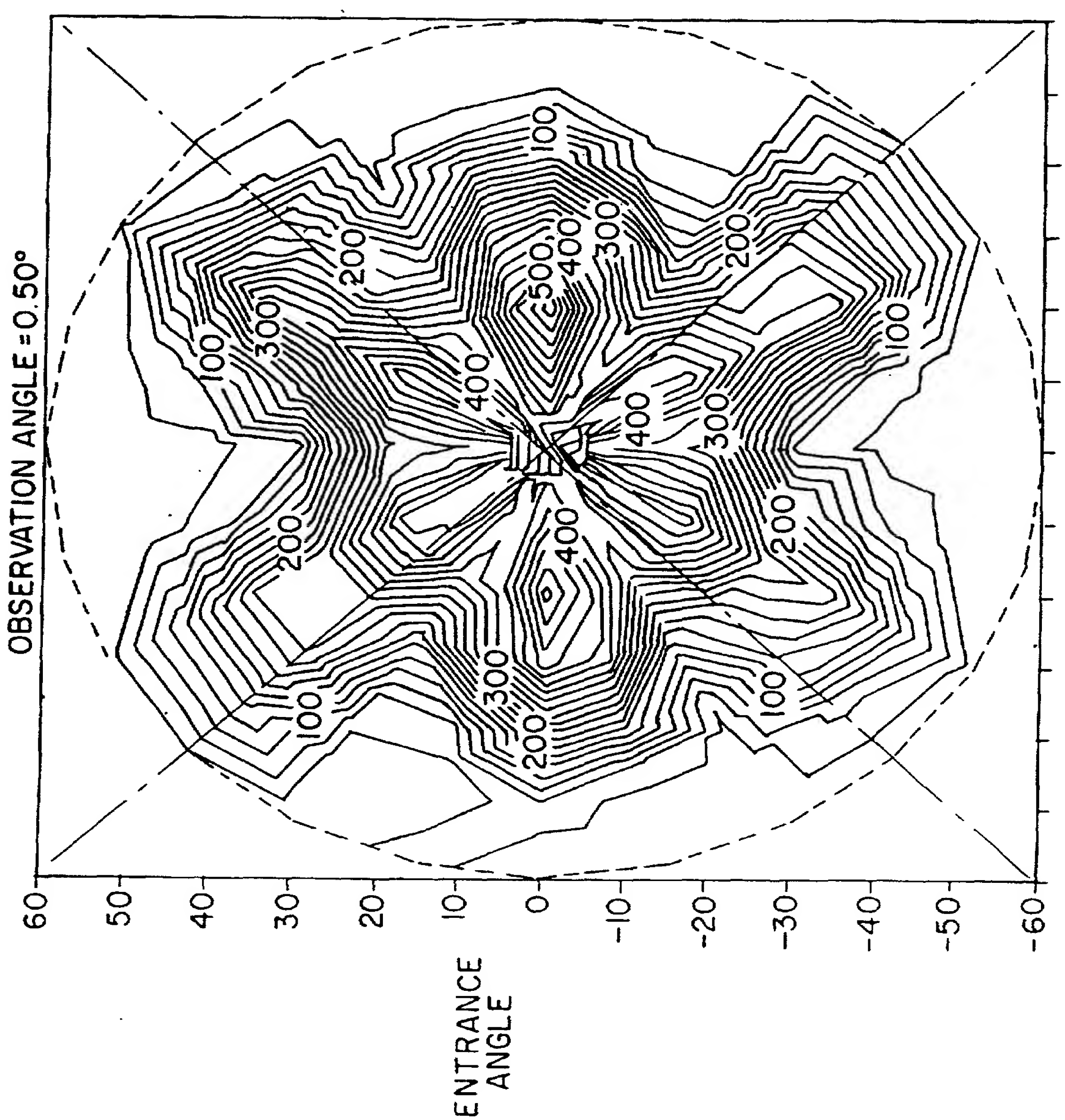
300
400
500

FIG. 25A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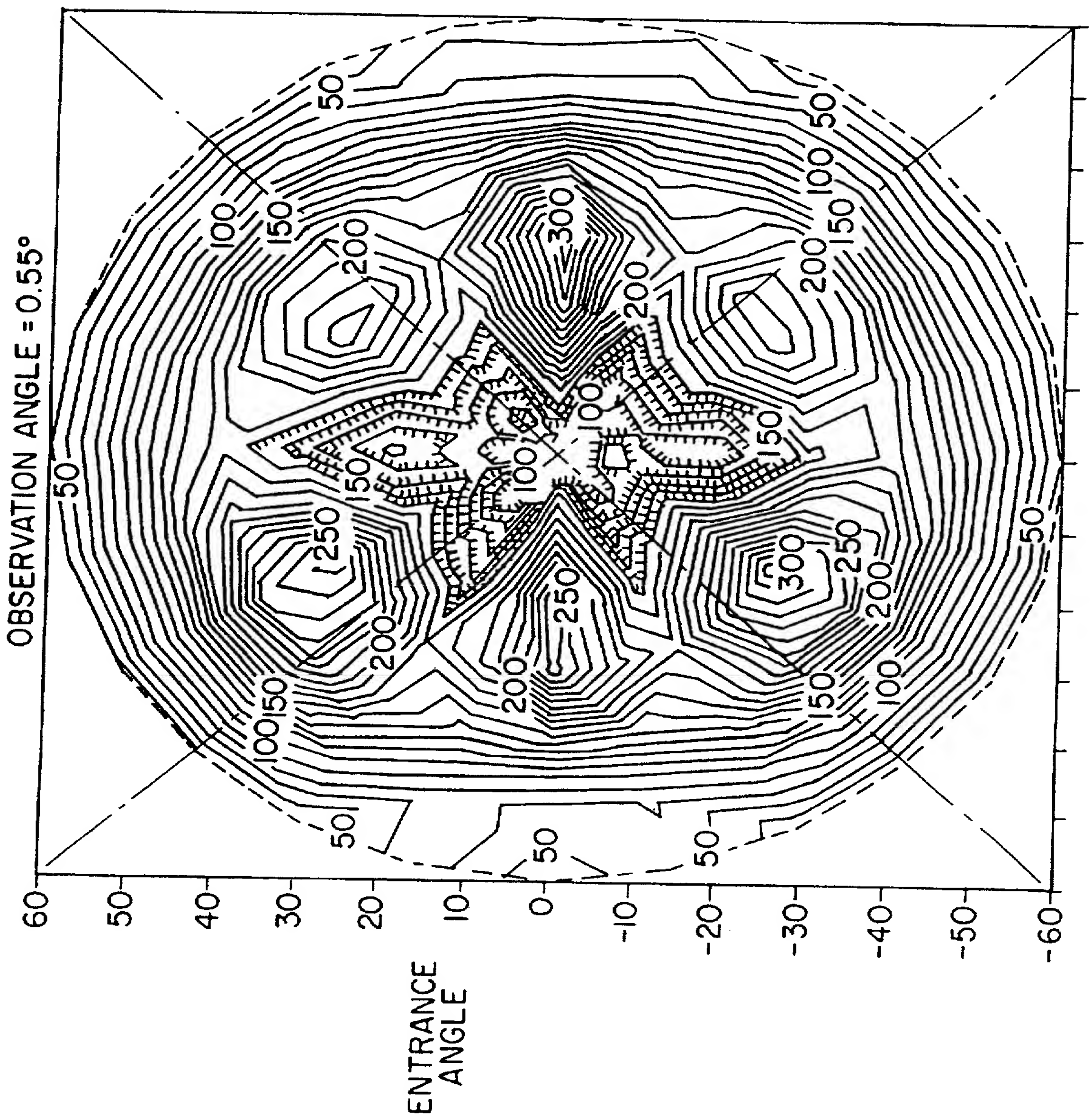
300
400
500

FIG. 25B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200
250
300

FIG. 25C

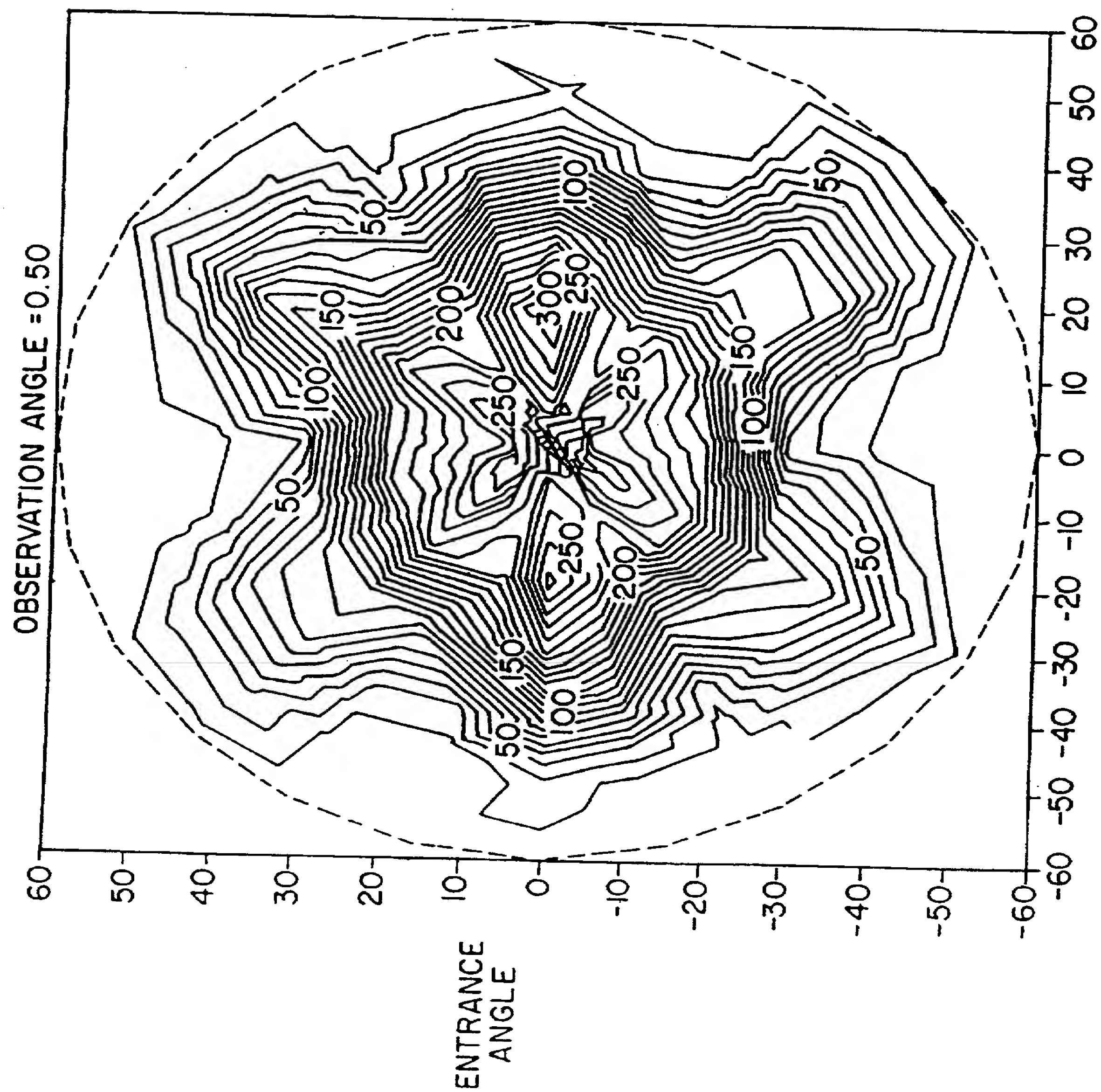
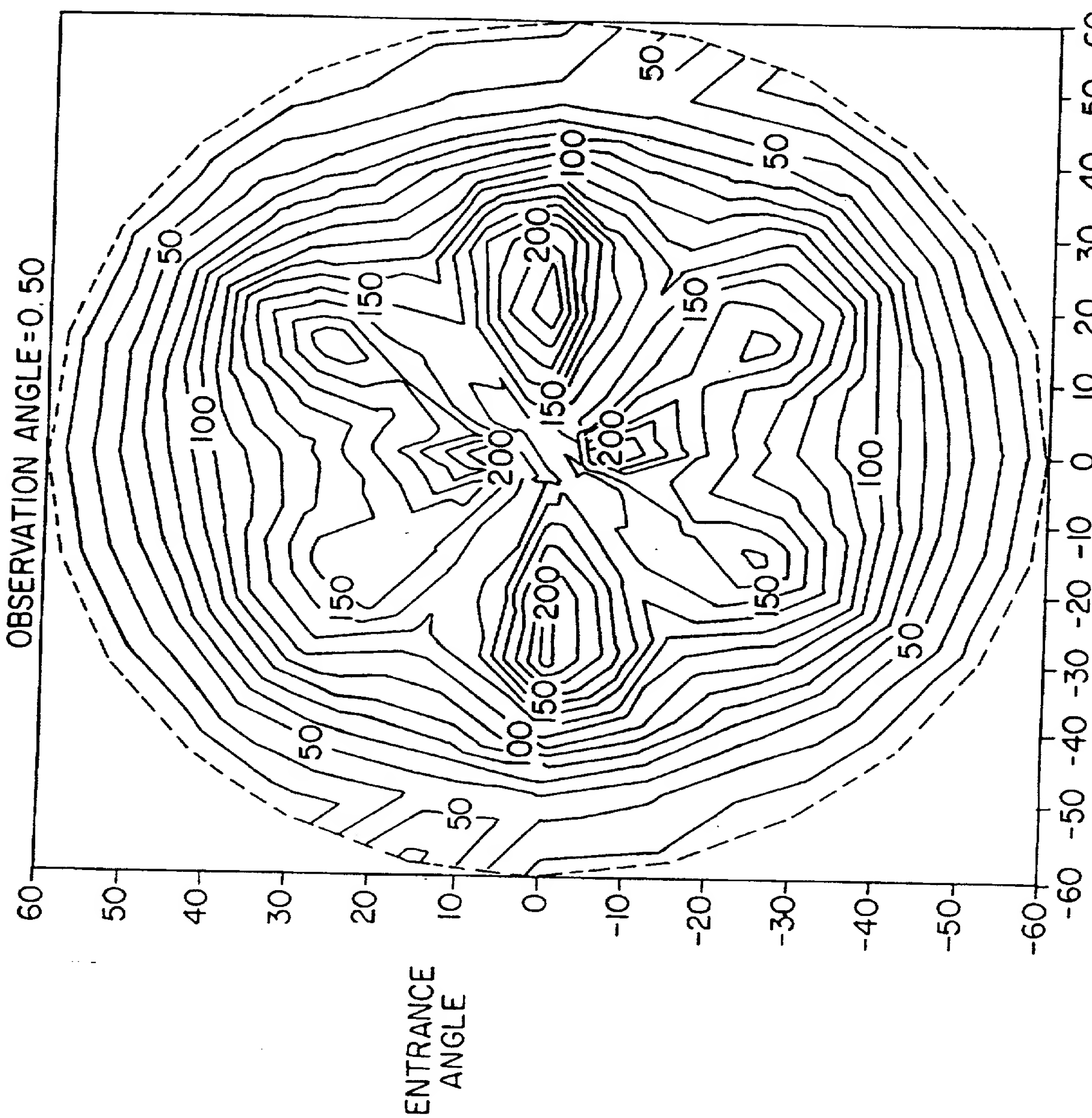


FIG. 25D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ENTRANCE ANGLE
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60 50 40 30 20 10 0 -10 -20 -30 -40 -50 -60
50
100
150
200

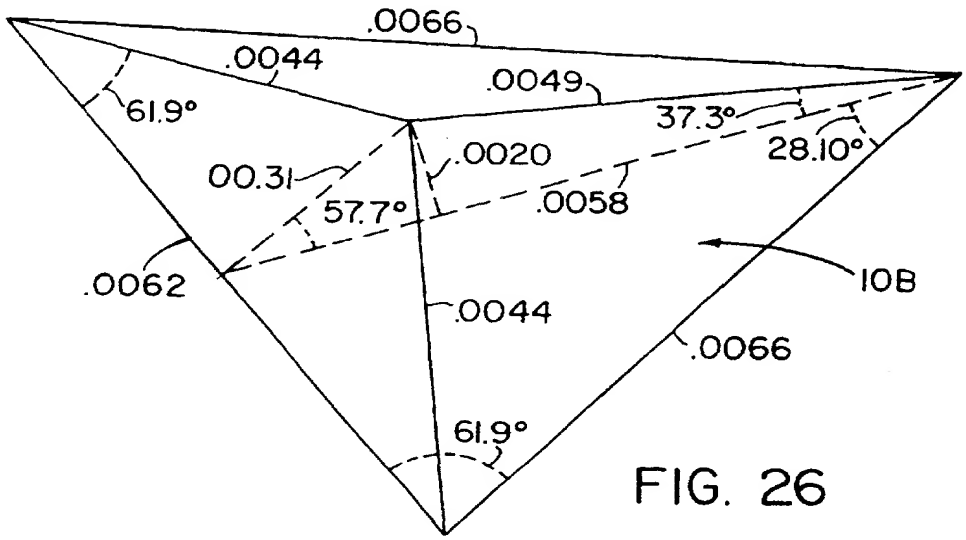
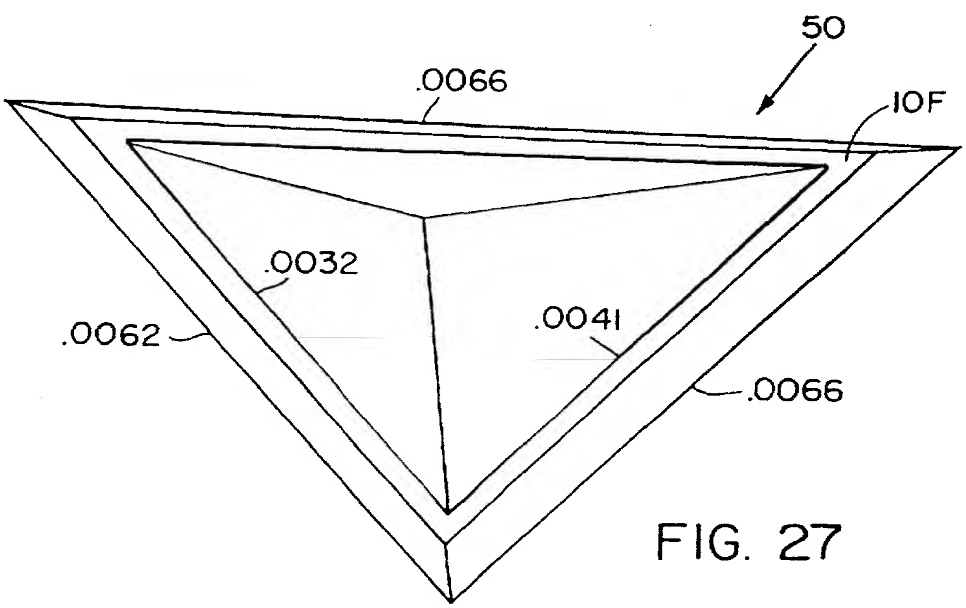

.0066
.0044
.0049
61.9°
37.3°
28.10°
.0020
00.31
57.7°
.0058
.0062
10B
.0044
.0066
61.9°

FIG. 26


50
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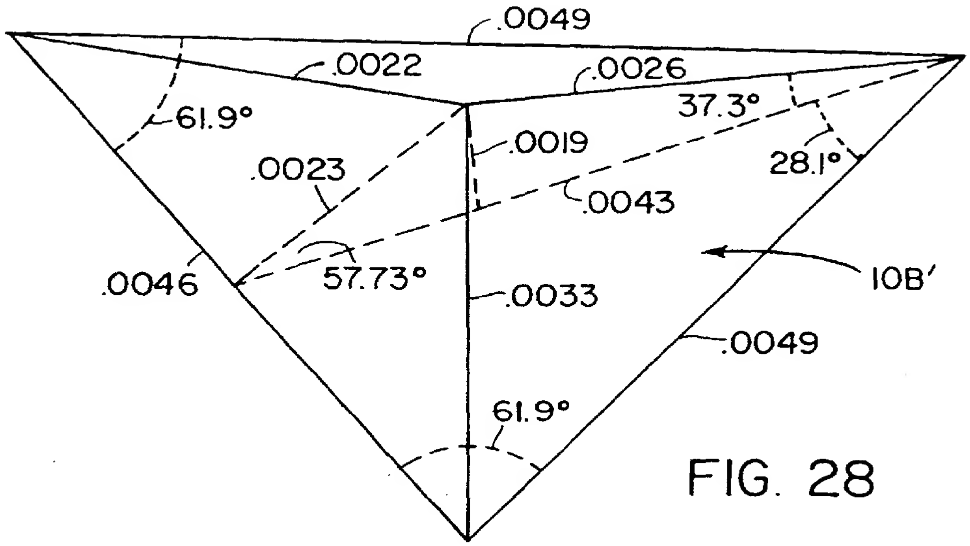
10F
.0032
.0062
.0041
.0066

FIG. 27


.0049
.0022
.0026
61.9°
37.3°
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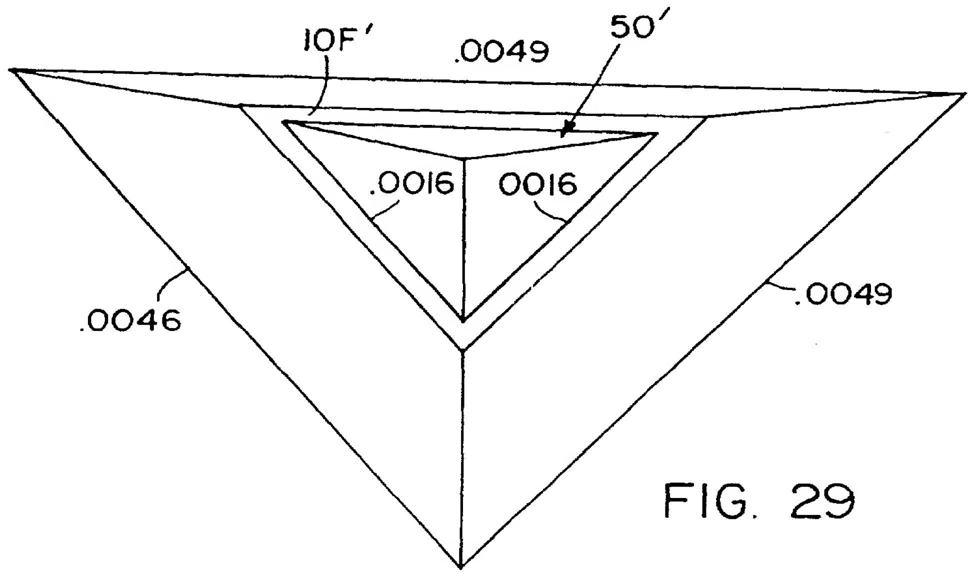
28.1°
.0023
.0043
.0046
57.73°
10B'
.0033
.0049
61.9°

FIG. 28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.0049
50'
.0016
0016
.0046
.0049

FIG. 29

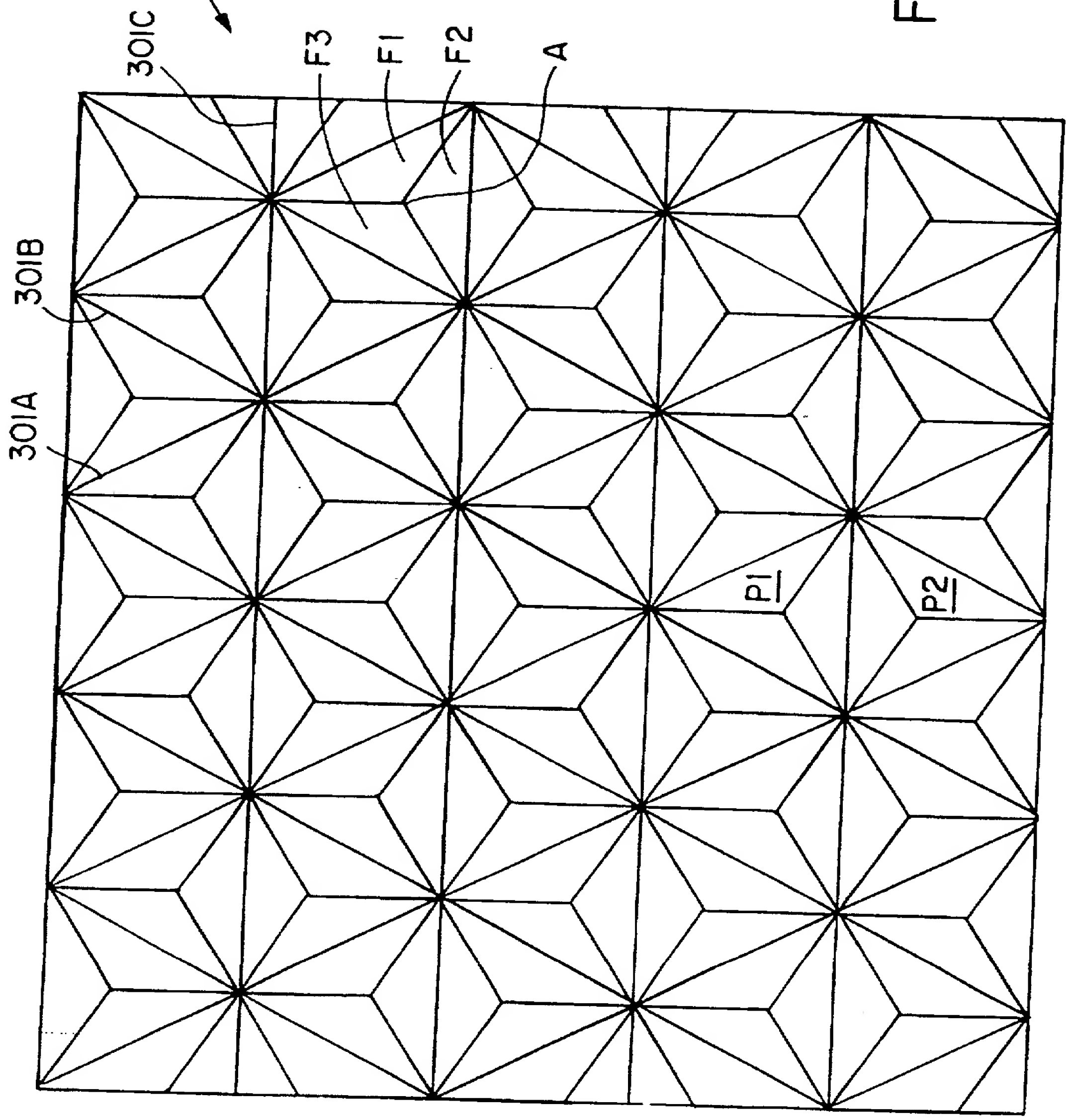

FIG. 30

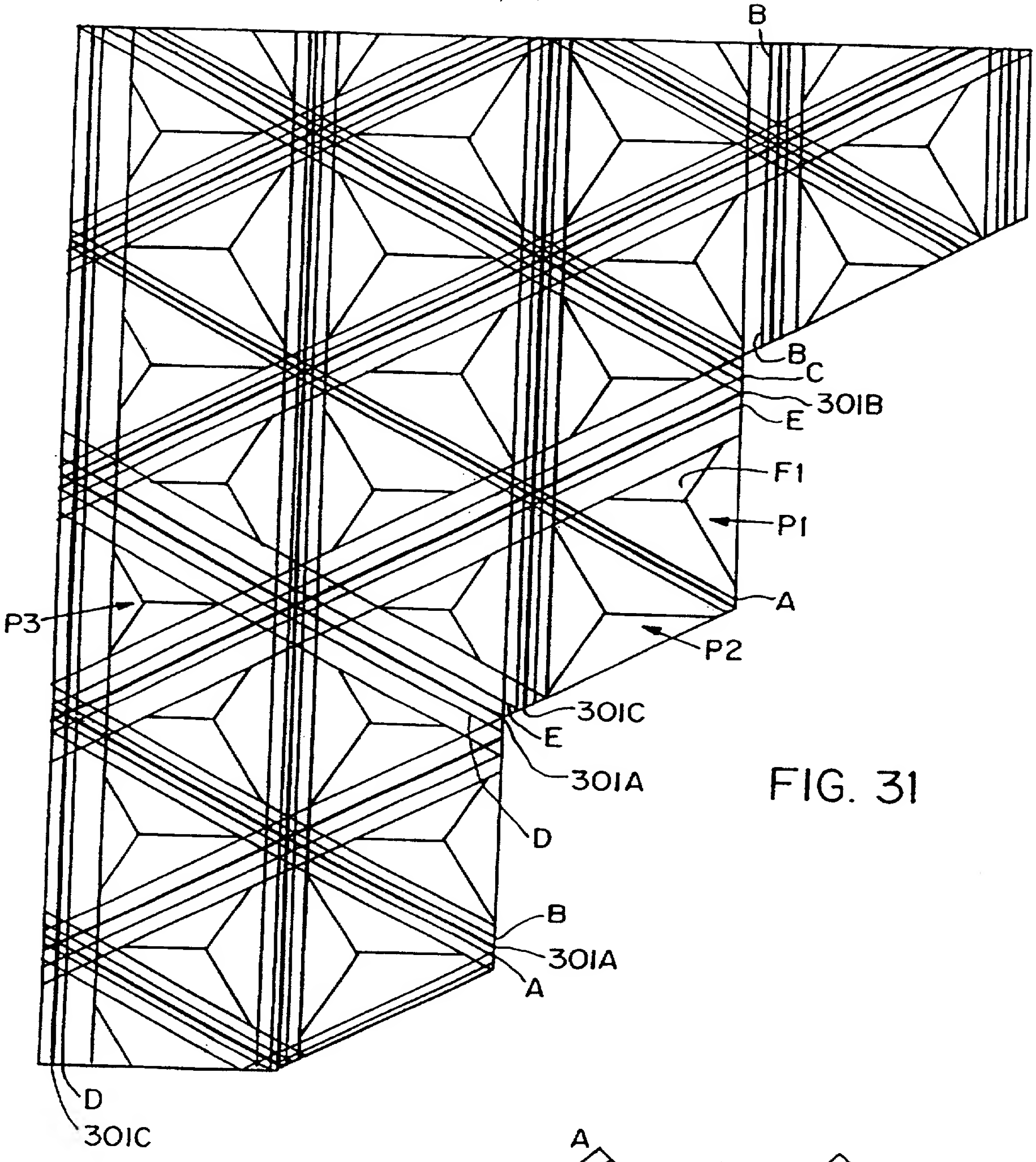

FIG. 31

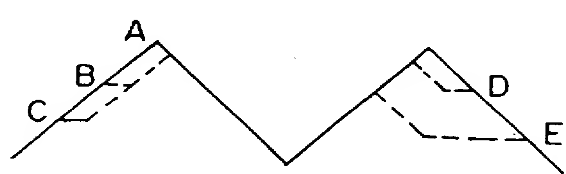

FIG. 32

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 95/11793

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 G02B5/124

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 G02B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	FR,A,2 662 819 (REFLEXITE) 6 December 1991 cited in the application see the whole document ---	1-38
A	EP,A,0 390 344 (MINNESOTA MINING AND MANUFACTURING) 3 October 1990 cited in the application see abstract; figures 1-5 ---	1,6,15, 24
A	EP,A,0 137 736 (MINNESOTA MINING AND MANUFACTURING) 17 April 1985 cited in the application see abstract; figures 1-7 ---	1,6,15, 24
	-/--	

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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"A" document defining the general state of the art which is not considered to be of particular relevance

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
11 January 1996	07.02.96

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax (+31-70) 340-3016	Malic, K

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US,A,3 712 706 (R.F.STAMM) 23 January 1973 cited in the application see abstract; figures 1-10 ---	1,6,15, 24
A	US,A,3 689 346 (W.P.ROWLAND) 5 September 1972 cited in the application see abstract; claims 1-14; figures 1-9 ---	7,9,28
A	US,A,4 244 683 (W.P.ROWLAND) 13 January 1981 cited in the application see abstract; figures 1-9 -----	7,9,28

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 95/11793

Patent document cited in search report	Publication date	Patent family member(s)		Publication date
FR-A-2662819	06-12-91	US-A-	5171624	15-12-92
		CA-A,C	2040909	02-12-91
		DE-A-	4117911	05-12-91
		GB-A,B	2245985	15-01-92
		JP-A-	4232903	21-08-92
EP-A-0390344	03-10-90	US-A-	5122902	16-06-92
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		AU-B-	616100	17-10-91
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		CA-A-	2010201	30-09-90
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		AU-B-	3223684	21-03-85
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		DE-A-	3485962	26-11-92
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		US-A-	4332847	01-06-82